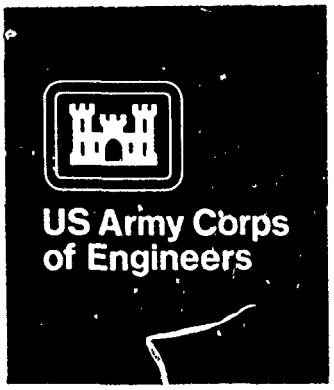

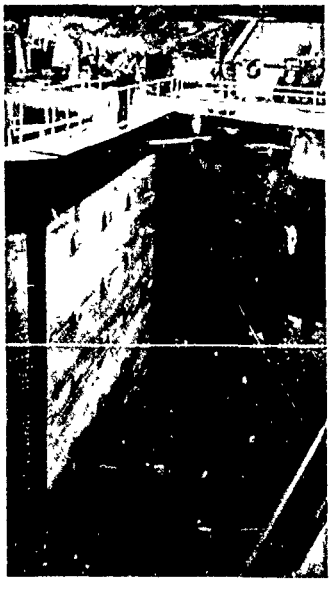

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REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT REMR-OM-1

EVALUATION OF EXISTING CONDITION RATING PROCEDURES FOR CIVIL WORKS STRUCTURES AND FACILITIES

by

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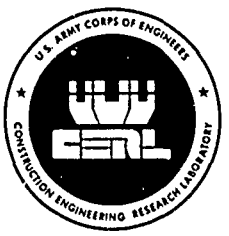

May 1986
Final Report

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This investigation has compiled information on numerous maintenance procedures used on civil works structures for the purpose of finding an overall procedure applicable to civil works projects. The information was obtained from available literature and from national and state agencies responsible for civil works maintenance programming.

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For each data source, a detailed inspection was made of the procedural components involved in maintenance procedures, such as checklists, manuals, rating systems, computer applications, technical and professional requirements, frequency of inspection, and repeatability. The various systems were then evaluated and compared. No appropriate rating system was found that applied directly to the periodic maintenance of civil works structures, and no system appeared to be easily usable and reliable when used by inexperienced raters. However, the Corps of Engineers Pavement Maintenance Management System (PAVER) and the Federal Highway Bridge Inspection Program appear to offer approaches that, with modifications, could be applied to Civil Works maintenance.

PREFACE

The study reported here was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Operations Management problem area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The work was performed under Work Unit 32280, "Development of Uniform Evaluation Procedures and Condition Index for Deteriorated Structures and Equipment," for which Dr. Anthony M. Kao is Principal Investigator. Mr. John R. Mikel (DAEN-CWO) is the REMR Technical Monitor for this work.

Mr. Jesse A. Pfeiffer, Jr., DAEN-RDC, is the REMR Coordinator at the Directorate of Research and Development, HQUSACE; Messrs. Mikel and Bruce L. McCartney (DAEN-CWH-D) and Dr. Tony C. Liu (DAEN-ECE-D) serve as the REMR Overview Committee; Mr. William F. McCleese (WESSC-A), U.S. Army Engineer Waterways Experiment Station, is the REMR Program Manager; Dr. Kao is also Problem Area Leader for the Operation Management problem area.

This work was conducted by the U.S. Army Construction Engineering Research Laboratory (USA-CERL) during the period October 1984 to December 1985 under the general supervision of Dr. R. Quattrone, Chief of the Engineering and Materials Division. COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

EVALUATION OF EXISTING CONDITION RATING PROCEDURES FOR CIVIL WORKS STRUCTURES AND FACILITIES

PART I: INTRODUCTION

Background

1. Civil works structures, which include highways, bridges, navigation, hydropower, and flood control facilities, and irrigation and drainage systems, are subject to varying degrees of deterioration. Periodic care and maintenance are required to prevent or decrease the development of any unsatisfactory condition, such as abutment erosion, concrete cracks, and seepage through the embankment or structural foundation. To obtain the longest life and most efficient use of these facilities, a maintenance program is required that includes reliable checklists and procedures to systematically improve and replace deteriorated elements.

2. Many state and national agencies as well as international organizations and private firms set standards for civil works maintenance programs. Among the most active U.S. organizations are the U.S. Army Corps of Engineers, the Bureau of Reclamation, the Resources Agency of the California Department of Water Resources, the Tennessee Valley Authority, and the Los Angeles Flood Control District. The American Society of Civil Engineers and the National Academy of Sciences are the most active of the national organizations in publishing manuals and reports on maintenance activities. Many of these agencies use checklists, computer data systems, and other schemes to maintain civil works structures under their jurisdictions.

3. Use of effective maintenance management procedures on the Corps of Engineers' civil works structures could greatly reduce costs and lengthen facility life. Also, personnel whose duties include inspection and maintenance procedures may often be inexperienced at this type of work. Therefore, a study was needed that would demonstrate not only how effective the various systems are, but also how easy they are to use.

Objective

4. The objectives of this study were to (a) ascertain the state of the art of existing evaluation methods and condition indexes and to determine if any present system can be adapted for use on civil works structures and (b) determine the efficiency and reliability of these methods when used by inexperienced personnel.

Approach

5. Numerous government and private agencies were contacted and a literature search was conducted to determine existing civil works maintenance rating procedures used by organizations that maintain these types of facilities. For each group, procedural components (e.g., checklists, manuals, rating systems, computer applications, technical and professional requirements, frequency of inspection, and repeatability) were recorded and evaluated.

6. Parts II through VIII of this report evaluate maintenance procedures of the following civil works structures and facilities: concrete dams and canals; rock and earth dams; spillways, stilling basins, and outlet works; lock walls, lock gates, and operating equipment; powerhouses and pumping plants; bridges and roads; and miscellaneous facilities. Tables in each chapter rate maintenance procedures according to whether they include the following criteria:

a. Checklists.
b. Manual (explanatory) for maintenance inspection procedures.
c. Rating system.
d. Computer application.
e. Technical evaluation with photographs.
f. Requirement of professional engineer.
g. Requirement of technical knowledge.
h. Repeatability (a term used for maintenance systems and procedures that will yield identical results when performed by different individuals).
i. Requirement of periodic inspection.

7. Agencies that use any or all of these criteria are indicated for each category of civil works structure. The appendices provide checklists, computer output, and other information applicable to each type of structure.

Mode of Technology Transfer

8. It is recommended that the results of this study be transferred through Engineer Technical Letters, Engineer Circulars, and the REMR Notebook (Ref. 29). No existing documents will be impacted by the results of this study.

PART II: CONCRETE/MASONRY DAMS AND CANALS

9. This chapter describes an investigation of maintenance programs conducted by agencies involved with operating concrete dams and canals. The agencies include two offices of the U.S. Army Corps of Engineers, the Bureau of Reclamation, the Los Angeles Flood Control District, the Tennessee Valley Authority, five state dam safety agencies, the Pacific Gas & Electric Company, and the Federal Emergency Management Agency. The following sections present detailed descriptions of the procedures used by these sources. Appendix A provides example checklists and information on concrete/masonry dams and canals.

Maintenance Inspection Procedures

U.S. Army Corps of Engineers

10. The Omaha District and Headquarters, U. S. Army Corps of Engineers (HQUSACE) have developed checklists to maintain and inspect concrete dams. However, neither program has a rating system that applies to the components of the maintenance tasks.

11. Omaha District. The Omaha District requires a technical inspection report consisting of photographs, interviews, notes, and data from monitoring devices. It requires that the observer construct an individual checklist for each site. This report, which is completed by an engineer, includes a descriptive section that assesses the general condition and offers an opinion about the urgency of repair. It also includes suggestions for possible remedial measures. A general guideline lists questions to be answered (Ref. 6) (see Figure A1).

12. HQUSACE. HQUSACE lists components that must be checked and conditions that should be monitored. Figure A2 lists the engineering data that must be included in any investigative report (Ref. 28).
The HQUSACE guidelines present instructions for inspecting concrete dams that may serve as the basis for developing detailed checklists. This information is very useful for dam safety inspections but cannot be directly used for other facilities.

Bureau of Reclamation

13. The Bureau of Reclamation supervises the operation and maintenance of a large number of concrete dams in the western United States. It also has programs for detecting and redressing deficiencies at these facilities. The programs provide for periodic on-site examination of the structures and the completion of comprehensive checklists.

14. The checklists generally do not have a rating criterion or computer approach to data collection. They are used as guides, but can become a permanent part of the reference material kept for a specific site. They can also be modified to consider each dam's individual features.

15. All of the Bureau's checklists generally consist of a short outline of information and special instructions for conducting the examination. For the most efficient examination, it is necessary to include sheets with a list of items requiring additional work and for recording special problems. Use of photographs is also common for identifying special features. The following sections discuss checklists and rating procedures for two of the Bureau's programs.

16. RO&M Program. The Review of Operation and Maintenance (RO&M) Program is a Bureau-wide activity that schedules examinations of all project facilities, including concrete dams. It considers facilities in three classes: major structures, special features, and minor facilities. Storage dams and more complicated diversion dams are among the major structures, while less complicated dams are considered minor facilities.

17. Examinations under the RO&M Program are conducted by project and regional personnel on a biannual or triannual basis. For efficiency, three categories of recommendations are made according to the importance of the problem:

a. Category 1: These recommendations relate to severe deficiencies, such as major cracks, in the concrete.

b. Category 2: Recommendations under this category cover a wide range of important matters in which action is required to prevent or reduce further damage.

c. Category 3: These recommendations are useful for the maintenance and consideration of less important items.

18. Figure A3 illustrates a checklist used by the RO&M Program for the maintenance of concrete dams (Refs. 8, 32). Space is provided for each item on the checklist for the comments of the rater/engineer.

19. SEED Program. The Safety Evaluation of Existing Dams (SEED) Program uses on-site examination and analysis to maintain the safety of concrete dams. The program includes an explanatory manual covering the Bureau's policies, principles, and concepts, as well as typical on-site examinations, examination reports, and checklists. Figure A4 illustrates a typical checklist (Ref. 34).

Los Angeles Flood Control District

20. The Los Angeles Flood Control District operates and maintains several flood-control reservoirs with a combined capacity of more than 106,000 acre-feet. Since debris swept down from steep mountain areas can be deposited on Los Angeles streets, causing property damage and loss of life, the district also operates and maintains debris dams and basins. For flooding protection, about 150 miles of permanent improvements have also been constructed; these consist of reinforced concrete channels and levees of riprap or concrete.

21. Following the Verdugo channel failure in September 1983, the district began an emergency program to identify, evaluate, and repair structural deficiencies in the open channel system. Because of the emergency action, it was concluded that under normal circumstances the structural inspection should be conducted by Operation and Maintenance (O&M) field personnel within the framework of the existing maintenance management system.

22. The inspections generally begin in March each year with sufficient resources allocated to conclude by the first of May. The district has provided detailed facility monitoring and inspection procedure for dams, debris basins, regulating basins, pumping plants, covered channels and storm drains, debris disposal areas, and inlets to underground systems.

23. A rating system for channel inverts and walls is also available based on the severity of their distress (Figure A5). For instance, the deterioration of a channel wall is low if the hole's cross-sectional area is less than 0.25 sq ft. The deterioration is considered medium if the hole's cross-sectional area is between 0.25 and 0.50 sq ft and high if the area is greater than 0.50 sq ft. The rating system also includes the extent and

condition of exposed steel, spalling and pitting, scour, slab cracking, ground water seepage, joint damage, faulting, slab bulging, and wall cracking. Figure A6 shows the application of these rating procedures using a checklist for a channel inspection.

Tennessee Valley Authority (TVA)

24. The TVA information includes a checklist used for concrete dam inspection (Ref. 40). The only rating categories on the list are "satisfactory" and "unsatisfactory." A space is provided for comments if a rating is unsatisfactory. Photographs are also taken as a record for comparison over a span of years. There is no detailed rating system used by the TVA, and the computer is not used for data collection.

25. Lengthy reports are written and recommendations made by civil, mechanical, and electrical engineers (Figure A7).

Ohio Department of Natural Resources

26. The Ohio Department of Natural Resources (ODNR) encourages owners to thoroughly inspect their facilities visually at least twice a year. The forms provided by the ODNR are helpful for these inspections (Ref. 20).

27. The dam inspection checklists have different parts, with one part dealing with concrete dams. The forms require observations by an inspector, and there is space for general comments, sketches, and field measurements. Figure A8 illustrates a concrete dam inspection checklist.

North Carolina Department of Environmental Resources

28. The Dam Safety Section of the North Carolina Department of Natural Resources has established a dam inspection checklist (Ref. 19), part of which can be used for concrete dams (see Figure B7 of Appendix B). Information must be provided for different parts of the facility, and a section is also included for comments. Examiners complete a followup inspection report. The checklist does not contain a rating system or manual.

Pennsylvania Department of Environmental Resources

29. The Pennsylvania Department of Environmental Resources publishes a checklist for an annual dam inspection (Ref. 1). The owner performs a

comprehensive visual examination and takes photographs to provide the Department of Environmental Resources with information about the facility's condition.

30. The concrete/masonry dam section of the inspection checklist (Figure A9) includes observations and recommendations/remarks on seepage, junction of structures, drains, foundations, cracking, spalling, and staff gage or recorder. The inventory provides a subjective evaluation of the dam and photographs. There is no rating system.

Colorado Division of Water Resources

31. The Colorado Division of Water Resources has developed the Dam Safety Manual, which is designed to provide specific guidance that will enable the owner to maintain a safe dam, avoid costly repairs, and prolong the facility life (Ref. 5).

32. The manual includes guides for visual inspection, seepage, upstream slope, crest, downstream slope, monitoring and instrumentation, maintenance, standard operating procedures, emergency plans, Colorado laws, and fundamentals of concrete dams. The chapter on concrete dams covers problems associated with this type of facility. These include structural cracks, foundation weaknesses, cracks at construction joints, shrinkage cracks, and deterioration from spalling.

33. The manual also contains specific information that applies to different types of dams. It includes many diagrams and photographs that should be easily understood by nontechnical personnel (see Figure B9 of Appendix B). This manual has a checklist, but does not have a rating system.

Kansas Division of Water Resources

34. The Water Structures Section of the Kansas State Division of Water Resources publishes a checklist for inspecting concrete/masonry dams (Ref. 16). The listing requires comments on engineering and construction data at the time it is considered during the inspection. There is no rating system.

Pacific Gas & Electric (PG&E) Company

35. PG&E regulations require a comprehensive inspection of all company dams once a year by an experienced engineering specialist. The engineer must

also be aware of the facility's past performance. To provide this information, the following four forms or reports are required for each inspection (Refs. 23, 24):

a. The "Water Collection Inspection Checklist" (Figure A10) is a comprehensive checklist that indicates any repair work or further inspection required.

b. The "Dam Inspection Report" consists of data and/or a description of the general condition of the dam's various functional parts. There is also space for listing any work required.

c. A summary of work required is sent to the appropriate PG&E department.

d. A report is submitted to the appropriate department after completion of the repair work.

36. If inspection shows any signs of overall instability, the proper authorities are informed immediately. Items in this category are noted by an asterisk in the "Water Collection Inspection Checklist."

37. Routine inspections are made more frequently by operating personnel assigned to the dams. It is recommended that the operator use the "Water Collection Inspection Checklist"; however, he/she need not complete the form. The Divisions must maintain a list of inadequacies and corresponding corrective actions. The appropriate department is notified of any critical problems.

38. Special inspections are performed immediately after occurrences such as a moderate earthquake in the area, flooding, and other possible causes of problems.

Federal Emergency Management Agency (FEMA)

39. The material provided by FEMA does not contain any form of checklist or rating system. However, the information found in Federal Guidelines for Dam Safety is pertinent to dam inspection (Ref. 9). It states that checklists should be prepared to cover the various structural, electrical, and mechanical features involved. It also recommends inspection every 5 years by a licensed professional engineer with expertise in investigation, design, construction, and operation of dams.

Evaluation

40. Most agencies emphasize checklists; however, the Los Angeles Flood Control District uses a rating system. Since none of the procedures reviewed appears to be repeatable, no appropriate overall rating system was found that may be directly used for periodic maintenance of concrete/masonry dams and canals.

41. None of the sources recommends any computer approach for data collection. However, some agencies require the expertise of a trained engineer or a person with technical knowledge to perform inspections. Only four organizations use manuals: the SEED Program of the Bureau of Reclamation, the Ohio Department of Natural Resources, the Colorado Division of Water Resources, and the Pacific Gas & Electric Dam Program.

42. Table 1 illustrates the evaluation of maintenance procedures of the sources.

PART III: ROCK AND EARTH DAMS

43. Information about the maintenance of rock and earth dams was obtained from the following organizations: U.S. Army Corps of Engineers Nashville District, Bureau of Reclamation, Resources Agency of California, Ohio Department of Natural Resources, Virginia Bureau of Water Control Management, North Carolina Department of Natural Resources, Pennsylvania Department of Environmental Resources, Colorado Division of Water Resources, and Kansas Division of Water Resources. The following sections provide details about specific procedures conducted at these sites. Appendix B provides example checklists and computer output for rock and earth dams.

Maintenance Inspection Procedures

U.S. Army Corps of Engineers

44. The Nashville District's maintenance manual includes a section on rock and earth fill dams (Ref. 18). Weekly visual observations are recommended for embankments and fills. Similarly, berm areas must be inspected weekly to check for irregularities such as caving, scour, erosion, seepage, settlement, burrowing animals, and need for mowing. Other areas of inspection include checking for erosion, slides, settlement, springs, boils, and other unusual conditions. Embankments and fills should be checked annually to detect leaks, settlement, excessive erosion, slides, lack of vegetation cover, and deterioration.

45. The maintenance program uses a checklist, manual, computer, and time schedule, but it requires some technical knowledge.

46. The manual contains a comprehensive maintenance task analysis that assigns an inspection routine to each task (Ref. 26). The tasks have been computerized, with four maintenance reports generated:

a. Maintenance work history (work and cost required to maintain items in the system).

b. Maintenance inspection report (items to be inspected and the date of inspection).

c. Delinquent report (items not inspected at the established time).

d. Maintenance summary report (labor required to maintain the items in the system).

Figure B1 shows examples of these four reports. Although this particular output applies to locks, the same type of report can be produced for rock and earth dams.

Bureau of Reclamation

47. The Bureau of Reclamation's RO&M Program has developed a checklist (Figure B2) for earth dams (Refs. 8,32). The RO&M maintenance procedures also require photographs and a technical report from a professional engineer. The Bureau's SEED Program also has a checklist for earth dams (Figure B3) (Ref. 34). These procedures use photographs and require a professional engineer.

Resources Agency of California

48. The Resources Agency of the State of California uses an inspection report for the San Luis Dam (Ref. 31); however, when compared with other checklists, the basic areas of inspection are quite similar. Dam condition is rated as requiring improvement, substandard condition, or standard condition.

49. The inspection form requires detailed inspection and photographs, but there is no manual that pertains directly to the facility. Generally, the dam and its related structures are inspected twice a year. Figure B4 illustrates the inspection form.

Ohio Department of Natural Resources

50. To provide for safe dams, dikes, and levees, the Ohio Department of Natural Resources (ODNR) has developed the Operation Maintenance and Inspection Manual (Ref. 20). The publication is designed to help owners maintain, operate, and inspect their facilities. It is nontechnical and easy to understand. Although emphasis is on the maintenance of small earth dams, the information can be applied to all types and sizes of dams as well as to dikes and levees. The sections that apply directly to small earth facilities are failure and emergency action, maintenance of embankments, and operation, inspection, and maintenance checklists.

51. The failure and emergency action section describes overtopping, seepage, and structural failures. This section also provides a step process for owners to follow in case of an emergency. The section on maintenance of embankments discusses and, in most cases, illustrates typical vegetation,

erosion, seepage, cracks, slides, settlement, rodent control, and monitoring devices. The operation section discusses lake drains, reservoir levels, recordkeeping, winterizing techniques, vandalism, design modifications, sedimentation and dredging, and low-head dams. The manual also provides basic instructions and a form for recording operation, maintenance, rainfall, and pool-level records.

52. The last section of the manual provides maintenance checklists. ODNR encourages owners to visually inspect their facilities thoroughly at least twice a year. The forms provided should help with inspection tasks. Although use of the checklists is not mandatory, the forms are used by the dam inspection section of the ODNR, and their use by owners is encouraged.

53. The dam inspection checklists include embankments, dikes and levees, and miscellaneous areas. They require observations by an inspector and specification of any required action. There is space for general comments, sketches, and field measurement. Although these checklists provide a thorough examination of dams during inspection, no rating system has been established. Figure B5 illustrates each type of checklist.

Virginia Bureau of Water Control Management

54. The Virginia Bureau of Water Control Management has compiled the pamphlet Safety Evaluation of Small Earth Dams (Ref. 35). The booklet presents general guidance to owners for inspecting and maintaining their structures. Although the information sets forth common problems, it is not intended to cover every type of condition, situation, or emergency that could render a facility unsafe. It also illustrates a "problem" dam and a "sound dam."

55. The pamphlet provides very basic information, with illustrations, about various types of dams and their principal parts, supplies information about inspection procedures, and furnishes checklists. The wording of the checklist (Figure B5) is general so that it can be applied to as many different facilities as possible, including the embankment, principal spillway, emergency spillway, reservoir area, downstream channel, watershed area, and the downstream region. A "yes" or "no" answer is required for all questions, and there is space for the inspector's comments. Maintenance tips are also supplied for each topic addressed by the questions.

56. The pamphlet also discusses maintenance priorities, stressing ongoing upkeep of the facilities. The outline for maintenance priorities is: what needs to be done at once, what needs to be done within the next year, and what needs to be done on a continuing basis. The last section of the pamphlet provides forms for recording dam history and inspections.

57. Safety Evaluation of Small Earth Dams tells how to evaluate the safety of a small earth dam and makes owners aware of general aspects of preventive maintenance. It can be understood easily by the layman. The checklists cover the major areas of dam maintenance, but there is no rating system.

North Carolina Department of Natural Resources

58. The North Carolina Department of Natural Resources and Community Development may inspect any dam at any time upon the request of any affected person or agency or upon a motion of the Environmental Management Commission. Therefore, it must assemble data needed to properly review and study the design and construction of dams, reservoirs, and appurtenances.

59. Dams should be examined every 2 or 5 years, depending on the particular type of construction. The department's Dam Safety section has developed a checklist (Figure B7) for inspecting earth dams, concrete dams, and spillways (Ref. 19). The checklist provides for recording information about different parts of the facility and allows space for comments. The inspectors use this information to complete a followup inspection report. The form does not contain a rating system and there is no manual.

Pennsylvania Department of Environmental Resources

60. The Pennsylvania Department of Environmental Resources has developed an inspection checklist to be used annually (Ref. 1). The facility owner uses the form to do a comprehensive visual examination, with photographs, that will provide the Department with information about the facility's condition.

61. The visual inspection forms (Figure B8) that apply to earth dams include embankment, reservoir and water shed, downstream channel, and instrumentation. The embankment section includes observation of cracks, movement, sloughing or erosion, crest alignment, riprap failure, seepage, drains, and junction of structures. The reservoir and watershed portion

provides recommendations on slopes, sedimentation, and watershed description. The downstream channel section includes observations and recommendations on condition, obstructions or debris, slopes, and population. The instrumentation section gives recommendations or remarks on monumentation, observation wells, weirs, and piezometers.

62. The checklist provides a subjective evaluation of dams, along with illustrative photographs. There is no rating system. However, the final report should indicate plans for correcting any deficiencies indicated by the inspection.

Colorado Division of Water Resources

63. The Colorado Division of Water Resources has developed the Dam Safety Manual (Ref. 5) to provide specific guidance for maintaining a safe dam, avoiding costly repairs, and prolonging facility life.

64. The manual covers fundamental dam components, visual inspection, seepage, upstream slope, crest, downstream slope, outlet system, spillways, concrete dams, monitoring and instrumentation, maintenance, standard operating procedures, emergency plans, and Colorado law.

65. The chapter on dam fundamentals diagramatically illustrates the various facility components and defines or discusses each one. This is an informative section for personnel who are not very familiar with dams.

66. The section dealing with visual inspection includes a checklist (Figure B9) and itemizes the equipment needed and its use.

67. The chapters on seepage, upstream slope, crest, downstream slope, outlet system, and spillways all have the same format. Several problems that commonly occur are described. There is a diagram or photograph of the problem, a description of the harm resulting from the problem and its causes, and corrective action needed. Figure B9 is an example. It is interesting to note that most actions require an engineer.

68. The chapter on concrete dams covers problems associated with concrete dams. This includes structural cracks, foundation weakness, cracks at construction joints, shrinkage cracks, and deterioration from spalling.

69. The presentation on monitoring and instrumentation provides descriptions and diagrams of monitoring devices. Special forms are included for recording measurements from drains, seepage and wet areas, and observation wells (Figure B9).

70. The chapter on dam maintenance includes methods for tree, brush, and weed control, earth placement, repair of rodent damage, filling in minor cracks, sealing reservoir basins, and rodent control.

71. The section on standard operating procedure presents activities schedules for high-hazard, moderate-hazard, or low-hazard dams.

72. The emergency plan chapter gives owners a written procedure to follow in case of an emergency. It lists potential problems and immediate actions to be taken if these problems occur. It also provides four forms to help owners prepare an emergency plan. The last chapter covers Colorado laws that relate to dams.

73. This manual can be understood easily by the layman. It has a checklist, but does not contain a rating system.

Kansas Division of Water Resources

74. The Water Structures Section of the Kansas Division of Water Resources has developed a checklist for dams that is patterned after the Corps of Engineers National Dam Inspection Program (Ref. 16). The checklist requires the inspector to comment on engineering and construction data as it is considered. The checklist (Figure B10) is divided into three sections: earth embankments, instrumentation, and reservoir. The drawbacks of this system are that the observations are subjective, and there is no rating system.

Other agencies and publications

75. Safety of Existing Dams is a 1983 publication of the National Academy of Sciences (Ref. 36). It includes a failure mode evaluation matrix for embankment dams (Figure B12) that includes slope failure, seepage, foundation movement, unprotected slopes, uplift, undermine, spillways, gates and hoists, obstructions, vandalism, outlet works, piping, and landslides.

76. The evaluation matrix also includes a tabulation of defects, possible indicators, possible causes, effects, and potential remedial measures associated with each failure mode. This type of information may be valuable when developing evaluation techniques.

Evaluation

77. Table 2 provides a comprehensive evaluation, in matrix form, of the maintenance procedures for rock and earth dams. None of the manuals and checklists used will completely fill the needs of a comprehensive maintenance program for rock and earth dams because none has a numerical rating system. It is also questionable whether the maintenance checklists are repeatable.

PART IV: SPILLWAYS, STILLING BASINS, AND OUTLET WORKS

78. Spillways and outlet works are generally inspected as part of the overall dam inspection process. This chapter discusses procedures used for those facilities by the following agencies: U.S. Army Corps of Engineers, Tennessee Valley Authority (TVA), Bureau of Reclamation (RO&M and SEED), Pacific Gas & Electric (PG&E), North Carolina Department of Natural Resources, Pennsylvania Department of Environmental Resources, Colorado Division of Water Resources, Kansas Division of Water Resources, Ohio Department of Natural Resources, and Virginia Bureau of Water Control Management. Appendix C provides example checklists for spillways, stilling basins, and outlet works.

Maintenance Inspection Procedures

79. Information about maintenance programs was obtained from several Corps of Engineers districts (Nashville, Omaha, Portland/Walla Walla, and Rock Island) and the Office of the Chief of Engineers.

80. The Nashville District and the Portland/Walla Walla Districts* have computerized maintenance programs. However, neither program has a rating system that can be applied to the maintenance task components.

81. The variety and scope of the submitted formats shows that there are several levels of sophistication among the districts, ranging from simple checklists to comprehensive computer tracking systems. However, none of these maintenance procedures has a rating component

Nashville District

82. The Nashville District has developed an extensive program that includes a detailed manual from the Operations Division of the Hydro-Power Branch (Ref. 18). This publication, which specifically addresses the maintenance of spillways and outlet works, consists of a comprehensive maintenance task analysis with an inspection routine assigned to each item. However, the manual appears to assume that the operator has a working

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*The Portland and Walla Walla Districts use the same procedures and forms, and are considered together for this discussion.

knowledge of the various tasks, malfunctions, states of repair, etc. The maintenance tasks have been computerized and four different maintenance reports are generated (Figure B1). The output is a very useful management tool for the allocation of personnel and cost, but the results neither reflect the state of deterioration nor prioritize items in the system. However, each item does have a maintenance notification card that lists the service required and the various codes, and provides space to record the inspection date and manpower commitment per job. It appears that all items are weighted equally and are repaired on an ongoing or as-needed basis.

Portland/Walla Walla District

83. Data for the Portland/Walla Walla District is similar to that of the Nashville District. They both use a project management data card system to maintain multipurpose and flood control projects (Ref. 27). Each card contains detailed descriptions, functions, and requirements for the piece of equipment being considered. A handwritten record is kept of each item on the preventive maintenance inspection and trouble report.

Omaha District

84. The Omaha District requires a technical report on the facility's condition that includes photographs, interviews, notes, and data from monitoring devices. The observer must first establish an individual checklist for each specific site. Using information from the checklist, an engineer then finishes the report, which includes a descriptive section evaluating the overall condition and an opinion about the immediacy of repair. The report also suggests possible remedial measures. A general guideline provides questions to be answered (Ref. 6).

Rock Island District

85. The Rock Island District has developed an inspection checklist for the spillways and outlet works on the Mississippi River under its jurisdiction (Ref. 33). The form has space for, and requires a comment on, each item. Figure C1 shows a questionnaire used specifically for the Saylorville Dam.

86. No manual or suggested procedure accompanies the checklist, so the type of support provided to ensure consistent judgment and repeatability of the inspection process cannot be determined.

HQUSACE

87. The information provided by HQUSACE does not include a rating system, but does list the components that must be checked and conditions that should be monitored (Ref. 28). Also included is a tabulation of engineering data that might be considered in any investigative report. Specifically, the report presents detailed instructions for inspecting spillways and calculating safety factors for dams (Figure A2).

Evaluation

88. All these organizations use checklists, but none uses a rating system. Table 3 gives an evaluation of the maintenance procedures of each agency or system.

PART V: LOCKS, LOCKWALLS, LOCKGATES, AND OPERATING EQUIPMENT

89. Four districts of the U.S. Army Corps of Engineers (Nashville, Portland, Walla Walla, and Rock Island) supplied information about maintenance programs for locks and associated facilities. The following sections provide detailed descriptions and/or checklists. Appendix D provides example checklists and information for lock walls, lockgates, and operating equipment.

Maintenance Inspection Procedures

Nashville District

90. The Operations Division of the Nashville District's Hydro-Power Branch has developed an extensive maintenance program that includes a detailed manual (Ref. 18). While the manual addresses the maintenance of dams (concrete, earth, and rockfill) and the associated equipment, the sample computer output studied is specifically for the Watts Bar Lock.

91. The program, which consists of a comprehensive maintenance task analysis, assigns an inspection routine to each task. However, the program appears to assume that the operator has a working knowledge of the various tasks, malfunctions, states of repair, etc. (Examples include: "Repair as necessary," "Do test," and "Maintain as required.") Tracking of these tasks has been computerized, and four different maintenance reports (Figure B1) are generated.

92. The output is a very effective management tool for allocating personnel and funds. Nevertheless, the results neither indicate the state of deterioration nor prioritize the items within the general maintenance system. Each item has a maintenance notification card that lists the services needed, the various codes, and a record of the inspection date and manpower commitment per job. All items appear to be weighted equally, and repairs are performed on an ongoing or as-needed basis.

93. The maintenance components in the Nashville plan include:

a. Checklist.

b. Manual.

c. Computer application.

d. Requirement of technical knowledge.

e. Time schedule.

Portland/Walla Walla Districts

94 The Portland/Walla Walla Districts generate data similar to that of the Nashville District. The sample computerized output considered for this study includes that generated for a lock network (Ref. 27). For example, items of repair associated with locks listed on the computer output show that a navigation lock staff gage was replaced, a handrail was painted, and a tainter valve was restored. The districts use a project management data card system; each card contains detailed descriptions, functions, and requirements for the equipment involved. A handwritten record for each item documents the preventive maintenance, inspection, and trouble reports investigated. Computerized output is also available that indicates the particular maintenance shop charged, the associated cost, and the manpower hours. Figure D1 gives a sample output list.

95. The Walla Walla District also has a system in which a 15-person inspection team performs a thorough structural investigation every 5 years. Their findings are published as an extensive technical report.

Rock Island District

96. The Rock Island District does not have a computerized approach, but does use an inspection checklist (Figure D2) for the locks and dams on the Mississippi River under its jurisdiction (Ref. 33). The documentation allows space for the inspector to comment on each item. These items include approach walls, lock walls, miter gates, and tainter valves, and they are evaluated by the condition and alignment of structural concrete, wall joints, and other general details. Gate valves, seals, and operating equipment are also considered.

Evaluation

97. The Nashville District and the Portland/Walla Walla Districts have developed very sophisticated computerized maintenance programs. While their formats are different, both approaches address similar items and generate typical information for tracking costs and managing manpower.

98. The Portland/Walla Walla and Rock Island Districts provided illustrative formats without supplementary documentation. The Sample Program Management cards indicate the amount of technical knowledge needed to perform the required maintenance tasks, the suggested frequency of inspection and the degree of repeatability. Of the systems reviewed, the card system of the Portland/Walla Walla Districts provides the most extensive and practical task analysis for equipment maintenance; however, a rating system is not used.

99. Table 4 gives a comprehensive evaluation, in matrix form, of the maintenance procedures for lock walls, lock gates, and operating equipment. Since there is no numerical rating system and it is questionable whether the results are repeatable, the checklists will not be adequate for a comprehensive maintenance program for locks, lockwalls, lockgates, and operating equipment.

PART VI: POWERHOUSES AND PUMPING PLANTS

100. A review of the literature concerned with powerhouse and pumping equipment and with instrumentation indicates that there are no specific maintenance programs for this category. However, these components are included as peripheral items to other facilities such as dams and locks.

101. The American Society of Civil Engineers (ASCE) has published an article (Ref. 21) on the operation and maintenance of irrigation and drainage systems. The components discussed include pumps and minor mechanical, electrical, and hydraulic equipment.

102. This chapter discusses procedures used for powerhouses and pumping plants by the U.S. Army Corps of Engineers, the Bureau of Reclamation, the Los Angeles Flood Control District, the Kansas Division of Water Resources, and the Federal Emergency Management Agency. The following sections provide detailed descriptions and/or checklists. Appendix E provides example checklists and computer output for powerhouses and pumping plants.

Maintenance Inspection Procedures

U.S. Army Corps of Engineers

103. Nashville District. The Nashville District's Operations Division of the Hydro-Power Branch has an extensive program that includes a detailed manual (Ref. 18) which addresses the maintenance of equipment associated with dams and outlines a maintenance task analysis and inspection routine for each item. However, these procedures assume that the operator comprehends the various tasks, existing malfunctions, states of repair, etc. Examples include: "Repair as necessary," "Do test," "Maintain as required." These tasks are tracked by computer, and four maintenance reports (Figures B1 and E1) are generated:

a. Maintenance work history (work and cost required to maintain items in the system).

b. Maintenance inspection report (items to be inspected and the date).

c. Delinquent report (items not inspected at the established time).

d. Maintenance summary report (labor required to maintain the items in the system).

104. This output appears to be a useful management tool for allocating personnel and funds, but the results neither reflect the state of deterioration nor prioritize items within the system. However, a maintenance notification card for each item tabulates recorded inspection dates and the cumulative manpower commitment per job. Figure E2 shows a maintenance notification card for switchboards. It appears that all items are weighted equally and are repaired on an ongoing or as-needed basis.

105. Portland/Walla Walla Districts. The Portland/Walla Walla Districts generate about the same information as the Nashville District. They have compiled a detailed inventory that describes each piece of mechanical and instrumentation equipment. To maintain their multipurpose power and flood control projects, these districts use a project management data card system. A handwritten record is kept on each item for the preventive maintenance, inspection, and trouble reports investigated (Figures D1 and E3). A computerized output shows the maintenance shop charged, the cost incurred, and the personnel hours used. The data cards present a comprehensive overview of the desired state of each piece of equipment. Components of this system are:

a. Checklist.

b. Manual.

c. Computer application.

d. Requirement of technical knowledge.

e. Repeatable.

f. Time schedule.

106. The Walla Walla District also requires a 15-person team to conduct a comprehensive structural investigation every 5 years. The results are presented in an extensive technical report.

Bureau of Reclamation

107. The Bureau of Reclamation supervises the operation and maintenance of a large number of dams and dikes in the western United States. Checklists have been developed for periodic on-site examination of these structures, but they are not adapted to computer application. The listings include structures such as power facilities and pumping plants and are open-ended so that only knowledgeable personnel can provide the desired feedback.

108. Review of Operation and Maintenance (RO&M) Program. The RO&M Program requires scheduled inspections of all project facilities, including power and pumping plants (Refs. 8, 32). Project and regional personnel examine all major, minor, and special features biannually or triannually. Figure E4 shows the checklist for pumping and powerhouse facilities. There are three categories of recommendations for each item:

a. Severe deficiencies: immediate action is needed to maintain structural safety or adequate functioning.

b. Action required to prevent or reduce further damage or an operational error.

c. Recommendations that are considered useful but less important than those of the first two categories.

109. These recommendations are identified and recorded as follows:

a. The first two digits indicate the year that the recommendation was made (80).

b. The third digit indicates one of the three recommendations categories (2).

c. A letter individualizes each recommendation made (a) (b) (c).

110. The components of this maintenance program are:

a. Checklist.

b. Technical evaluation.

c. Requirement of professional engineer.

d. Requirement of technical knowledge.

e. Rating system.

f. Frequency of inspection.

111. Safety Evaluation of Existing Dams (SEED). The Bureau's program includes checklists for dams and power facilities, but is a guideline rather than a specific maintenance program. This program uses on-site examination and analysis to maintain facility safety (Ref. 34). Checklists are organized like those of the RO&M program. Information for outlet works and power features is included in the checklist (see Figure E5).

112. Checklists are to be used as guides and are not to limit the examination. They can become a permanent part of the Bureau's reference materials. Each checklist is individualized for the specific site, so the general checklist must be kept updated as required.

113. The Bureau's checklists consist of a short outline of information and special instructions for the examination. Sheets must be included for

special items, additional notes, and identification of unique features. Photographs are also taken to maintain an historical record.

114. The components of this maintenance program are:

a. Checklist.

b. Manual.

c. Technical evaluation.

d. Requirement of professional engineer.

e. Requirement of technical knowledge.

f. Frequency of inspection.

Los Angeles Flood Control District

115. The Los Angeles Flood Control District operates and maintains several flood control reservoirs. After the Verdugo Wash Channel failure in September 1983, the district started an emergency program to identify, evaluate, and repair structural deficiencies in the open channel system (Ref. 17). It was concluded that under normal circumstances the structural inspection should be conducted by operations and maintenance field personnel within the framework of the existing maintenance management system. A checklist and a rating procedure have been developed (Figure A5), and a detailed facility monitoring and inspection procedure (Figure A6) is also used.

116. The components of this maintenance program are:

a. Checklist.

b. Manual.

c. Technical evaluation.

d. Requirement of professional engineer.

e. Requirement of technical knowledge.

f. Repeatability.

g. Frequency of inspection.

The district's checklist and maintenance rating procedures also include care of pumping plants.

Kansas Division of Water Resources

117. The water structures section of the Kansas State Division of Water Resources has patterned its checklist (Figure E6) for dams after the Corps of Engineers' National Dam Inspection Program. The checklist requires comments

on engineering and construction data as the data are examined, and items on the form also address instrumentation (Ref. 16). The observations made in filling out the checklist are subjective.

Federal Emergency Management Agency (FEMA)

118. FEMA does not have any form of checklist or rating system for powerhouses and pumping plants. Nevertheless, they suggest that checklists be prepared for the various structural, electrical, and mechanical features of powerhouses and pumping plants. Also the inspection should be conducted by a licensed professional engineer experienced in the investigation, design, construction, and operation of dams. The recommended frequency of inspection is once every 5 years.

Evaluation

119. Table 5 illustrates, in matrix form, the evaluation of maintenance procedures for powerhouses and pumping plants. Of the programs reviewed, the individual cards used by the Portland/Walla Walla Districts provide the most extensive task analysis for equipment maintenance. Most agencies and publications emphasize checklists, but only the Los Angeles Flood Control District uses a rating system. Since none of the procedures appears to be repeatable, no appropriate rating system was found that applies directly to maintenance of powerhouses and pumping plants.

PART VII: BRIDGES AND ROADS

120. This chapter outlines maintenance programs used by three programs responsible for maintaining roads and highways: the Federal Highway Administration's Bridge Replacement and Rehabilitation Programs, the Corps of Engineers' Pavement Maintenance Management for Roads and Parking Lots (PAVER), and the Indiana Department of Highways manual. The following sections provide details about these programs. Appendix F provides examples for bridges and roads.

Maintenance Inspection Procedures

Federal Highway Bridge Replacement and Rehabilitation Program

121. The Federal Highway Administration developed the Bridge Replacement and Rehabilitation Program for state highway departments to use in rating the condition of bridges and tunnels (Ref. 30). The program uses trained technicians rather than professional engineers to inspect structures. The inspection procedures have been simplified so that different trained technicians who inspect the same bridge would be likely to produce identical evaluations. Thus, the process is repeatable.

122. To determine the condition of a bridge, the technician checks each component of the structure and assigns it a rating number from 0 to 9 (Figure F1). These values are recorded on an inspection checklist. When the inspection is completed, the values are transferred to a computer input sheet. Use of this system requires knowing the bridge's dimensions, which are used to calculate the facility's functional obsolescence and safety. The checklist ratings and dimensions are then considered in calculating the overall sufficiency rating.

123. This is an excellent system that could easily be adapted for rating and maintaining civil works structures and facilities.

Corps of Engineers' Pavement Maintenance Management for Roads and Parking Lots (PAVER)

124. The PAVER system is used to inspect and rate the pavement of roads and parking lots (Ref. 39). The system is designed to help optimize the allocation of pavement repair funds.

125. The first step in the rating procedure is dividing the pavement network into manageable sections. Each section is then further subdivided into sample units. Each unit is given a pavement condition index (PCI) rating related to its structural integrity, structural capacity, roughness, skid resistance, hydroplaning potential, and deterioration rate. The PCI scale ranges from 0 to 100. A separate inspection form is required for each sample unit. Nineteen different distress types may be used in assigning the PCI value. In each pavement section, the type, diversity, severity, and the PCI reduction number are determined and recorded.

126. The overall PCI may be computed by subtracting the sum of the reductions from 100. The deterioration rate can also be determined by placing this value along with the PCI from previous years on a PCI-versus-time graph.

127. This system provides for a repeatable procedure for rating road condition. A manual is available that contains a series of photographs representing examples of high-, medium- and low-severity pavement distress.

128. Figure F2 shows an example of the PCI scale and condition rating and illustrates the computer output for PAVER.

Indiana Department of Highways

129. The Indiana Department of Highways' publication, Development and Use of a Management Information System to Identify Areas of Routine Maintenance Productivity Improvement was reviewed (Ref. 38). The review did not investigate the methods used to rate or check the condition of roads and bridges. Instead, it dealt with the results of studies performed to analyze fund distribution methods. Findings pertinent to this investigation that may be used during the development and operation of a comprehensive maintenance management system were as follows:

a. In a study performed by the Pennsylvania Department of Transportation, an inverse relationship was found between efficiency and quality of work.

b. Specific maintenance actions are rarely consistently recommended following a report of specific problems.

c. Although the amount of money spent on repairs increases with the number of lane-miles, the relationship is not directly proportional.

Evaluation

130. Table 6 is an evaluation matrix of the maintenance procedures for bridges and roads. Both the Federal Highway Administration and PAVER have a systematic, repeatable rating system. They also both have an exceptional range of qualities that may be useful for developing an overall maintenance management system for bridges and roads.

PART VIII: MISCELLANEOUS FACILITIES

131. Because of the variety of miscellaneous facilities investigated, evaluations were made on the merits of each program rather than in reference to a particular facility type (Refs. 3, 11, 12). Organizations involved included the Training and Doctrine Command (TRADOC), the Forces Command (FORSCOM), Southwestern Division of the U.S. Army Corps of Engineers, and the Resources Agency of the State of California. The following sections summarize each organization's procedures. Appendix G provides example checklists and information for miscellaneous facilities.

Maintenance Inspection Procedures

TRADOC's BMAR and DMAR Rating Systems

132. The purpose of TRADOC'S BMAR (Backlog of Maintenance and Repair) and DMAR (Deferred Maintenance and Repair) rating systems is to facilitate the distribution of available funds for maintenance and repair projects on U.S. Army installations (Refs. 2, 42).

133. Both systems involve the following steps:

a. Compilation of necessary information for a project by an installation officer.

b. Verification of the project by a TRADOC validator.

c. Decision on funding: the TRADOC score and the existing design status are the two items used to determine the funding ratio among competing projects. The TRADOC score, which is assigned by the TRADOC validator, reflects the project's overall degree of need. The design status is a statement of the condition of readiness to begin work on the project.

134. For BMAR, the scoring is determined by the following five major groups:

a. Functional use of the facility.

b. Justification factors related to maintenance and repair.

c. Type of project (choose one of the following):

(1) Buildings and grounds.

(2) Utilities.

d. Condition of the facility.

e. Priority assigned by the installation.

135. For DMAR, the scoring is determined by the following five major groups:

a. Category of family housing.

b. Category of requirement.

c. Type of work.

d. Condition of the facility.

e. Priority assigned by the installation.

136. Each of the five major groups in both BMAR and DMAR are further divided into areas that are assigned a numerical rating between 1 and 10. Figure G1 gives an example of this detailed breakdown.

137. The ratings obtained from the first four groups in both BMAR and DMAR are added to obtain the "base score." The sum of the "base score" and the rating value calculated from the project's priority is multiplied by 1000 to obtain the "TRADOC score."

138. The rating value is obtained from an expression that alters the assigned priority number so that a priority of 1 translates to a rating value of 10, and those with second, third, etc., priority numbers receive rating values that are progressively less than 10. Figure G2 gives a sample listing of some BMAR project ratings and scores.

FORSCOM Regulation 420-3

139. The purpose of FORSCOM Regulation 420-3 is to set priorities on maintenance and repair projects for all FORSCOM installations and subinstallations. The FORSCOM procedure includes three main steps (Refs. 10, 15):

a. The installation lists its maintenance and repair projects. Then reports, which include a general information sheet and a rating worksheet for each project, are sent to the FORSCOM authorities.

b. A FORSCOM Technical Service Division representative visits the installation, reviews the project priority system used, and decides whether to approve it. A spotcheck of all project documents is also made.

c. A decision is made on funding. Funding is based on several items, including the following:

(1) FORSCOM's priority score. Besides its own priority score, FORSCOM will also consider the priority given to the project by the installation.

(2) Results from FORSCOM's field reviews.

(3) The project status. The project status indicates the ability to design and/or obligate funds for the project during the current fiscal year.

140. The project rating system recommended by FORSCOM is divided into five categories:

a. Facilities use factor.

b. Project purpose factor.

c. Project type factor.

d. Mission factor.

e. Condition factor.

141. Each factor is further subdivided into functional areas which are assigned a rating range that varies from eight to ten. Figure G3 provides additional details. An intermediate score is then obtained by adding all the rating values from the five categories. The final score for the project is determined by adding the intermediate score to the priority rating score and multiplying the sum by 1000.

142. The priority rating score is obtained by an expression which alters the assigned priority number so that a priority of 1 gets a score of 10, and those with second, third, etc., priorities get values that are progressively less than 10.

U.S. Army Corps of Engineers, Southwestern Division

143. The Southwestern Division has submitted a proposal for a project operation and maintenance funding level matrix (Ref. 22). Since this appears to be an application of global program development and justification rather than a specific itemization of maintenance procedures, considerable modification may be necessary for it to be useful for civil works projects. Figure G4 is a sample entry of this matrix.

The Resources Agency of the State of California

144. The Resources Agency of the State of California has developed inspection reports for operation and maintenance of aqueducts and dams based on the following rating system (Ref. 31):

a. P: Poor quality

b. G: Good quality

c. E: Excellent quality

d. N.C.: No change in quality

145. Figure G5 shows an example of this procedure. Photographs and specific remarks are also required. Generally, headquarters personnel inspect the aqueducts about once a year. However, dams and related structures are usually inspected twice a year. This procedure involves, in part, a general checklist. However, except for dams, the checklists do not have a comprehensive rating system.

Evaluation

146. Table 7 illustrates, in matrix form, the evaluation of maintenance procedures for miscellaneous facilities. TRADOC and FORSCOM maintenance and repair funding programs use basically the same procedures with some minor internal differences. Both deal with the maintenance and repair of facilities on U.S. Army installations. Each uses a numerical rating system that helps compare projects. Actual rating procedures appear to be repeatable if the raters are experienced and have completed a comprehensive training course. Therefore, both systems appear to offer approaches that, with modification, may be applicable for developing a comprehensive maintenance management program.

PART IX: CONCLUSIONS

147. This report has described and evaluated various maintenance procedures related to several civil works (type) structures and facilities. Most of the procedures studied for this research include the use of checklists for maintenance and review operations. However, TRADOC, FORSCOM, and FEMA do not use the checklist format. Twelve agencies have developed manuals and/or explanatory materials for maintenance systems. Various other rating systems are used by eight sources. Most of the rating systems evaluate facilities according to the following categories: yes/no, satisfactory/unsatisfactory, high/medium/low, excellent/good/fair/no change/bad/critical, etc. Five sources use a computer data bank to assist in maintenance operations, and eight sources require the use of photographs in technical evaluations.

148. Sixteen sources require professional engineering and technical knowledge to conduct maintenance evaluations. The structures which need professional engineering services and/or technical knowledge for maintenance and inspection include spillways, stilling basins, rock and earth embankments, shore and bank stabilization, bridges, lockwalls and gates, powerhouse equipment, and various miscellaneous facilities. Repeatable systems also generally require extensive training and explanatory guidelines. Only four systems were found to be repeatable.

149. For most maintenance systems, it is vital to have a time schedule or an overall frequency of inspection plan. Fifteen sources were found to inspect their facilities at specific time schedules.

150. No specific or uniform pattern was observed among the procedures studied that can be used as a general guideline for civil works maintenance. The facilities differ markedly in their nature, purpose and use, amount and type of building material, geographical location, environmental and geological condition, and physical, mechanical, engineering, and architectural aspects. Therefore, no appropriate overall rating system was found to apply directly to the periodic maintenance of civil works structures, and no system appeared to be easily usable and reliable when used by inexperienced raters. However, the Corps of Engineers' PAVER and the Federal Highway Bridge Inspection Program appear to offer approaches that, with modification, may be applicable to certain types of civil works structures.

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Table 1

Summary of Existing Maintenance Procedures for Concrete/Masonry Dams

Procedures / Code List	Pennsylvania Department of Environmental Resources	Colorado Division of Water Resources	Kansas Division of Water Resources	Pacific Gas & Electric Company	Federal Emergency Management Agency	Operation & Maintenance o Irrigation & Drainage Systems	The Engineering of Large Dams	Safety of Existing Dams	U. S. Army Corps of Engineers (Omaha District)	U. S. Army Corps of Engineers (Office of Chief Engineer)	Bureau of Reclamation (R O & M Program)	Bureau of Reclamation (SEED Program)	Los Angeles Flood Control District	Tennessee Valley Authority	Ohio Department of Natural Resources	North Carolina Department of Natural Resources
1. Checklist	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2. Manual (explanatory)		✓		✓								✓			✓	
3. Rating System													✓			
4. Computer Application																
5. Technical evaluation w/o photographs									✓		✓	✓		✓		
6. Requires professional engineer				✓		✓	✓				✓	✓		✓		
7. Requires technical knowledge						✓	✓		✓		✓	✓		✓		
8. Repeatability																
9. Frequency of inspection	✓			✓		✓	✓				✓	✓		✓	✓	

Table 2

Summary of Existing Maintenance Procedures for Rock and Earth Dams

Procedures / Code List	U. S. Army Corps of Engineers Nashville District	U. S. Army Corps of Engineers Rock Island District	Bureau of Reclamation R O & M Program	Bureau of Reclamation SEED Program	Resources Agency of California	Ohio Department of Natural Resources	Virginia Bureau of Water Control Management	North Carolina Department of Natural Resources	Pennsylvania Department of Environmental Resources	Colorado Division of Water Resources	Kansas Division of Water Resources	Operation & Maintenance of Irrigation & Drainage Systems	Safety of Small Dams	Safety of Existing Dams (NASP)
1. Checklist	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
2. Manual (explanatory)	✓			✓		✓	✓			✓				✓
3. Rating System														
4. Computer Application	✓													
5. Technical evaluation w/o photographs			✓	✓										✓
6. Requires professional engineer			✓	✓									✓	✓
7. Requires technical knowledge	✓		✓	✓									✓	✓
8. Repeatability														
9. Frequency of Inspection	✓		✓	✓	✓			✓	✓	✓				

Table 3

Summary of Existing Maintenance Procedures for Spillways, Stilling Basins, and Outlet Works

Procedures / Code List	U. S. Army Corps of Engineers Nashville District	Portland District	Omaha District	Rock Island District	HQUSACE	Bureau of Reclamation R O & M Program	Bureau of Reclamation SEED Program	Tennessee Valley Authority	Pacific Gas & Electric	Safety of Small Dams	Safety of Existing Dams	Ohio Department of Natural Resources	Virginia Bureau of Water Control Management	North Carolina Dept. of Natural Resources	Pennsylvania Dept. of Environmental Resources	Colorado Division of Water Resources	Kansas Division of Water Resources
1 Checklist	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓	✓
2. Manual (explanatory)	✓	✓					✓		✓			✓	✓			✓	
3. Rating System																	
4. Computer Application	✓	✓															
5. Technical evaluation w/o photographs			✓			✓	✓										
6. Requires professional engineer			✓			✓	✓		✓								
7. Requires technical knowledge	✓	✓				✓	✓										
8 Repeatability																	
9. Frequency of inspection	✓	✓				✓	✓	✓	✓			✓		✓	✓	✓	

Table 4

Summary of Existing Maintenance Procedures for Locks, Lockwalls, Lockgates, and Operating Equipment

Procedures / Code List	U. S. Army Corps of Engineers Nashville District	U. S. Army Corps of Engineers Portland/Walla Walla	U. S. Army Corps of Engineers Rock Island District
1. Checklist	✓	✓	✓
2. Manual (explanatory)	✓	✓	
3. Rating System			
4. Computer Application	✓	✓	
5. Technical evaluation w/o photographs			
6. Requires professional engineer			
7. Requires technical knowledge	✓	✓	
8. Repearability			
9. Frequency of inspection	✓	✓	

Table 5

Summary of Existing Maintenance Procedures for Powerhouses and Pumping Plants

Procedures / Code List	U. S. Army Corps of Engineers Nashville District	U. S. Army Corps of Engineers Portland/Walla Walla	Bureau of Reclamation R O & M Program	Bureau of Reclamation SEED	Los Angeles Flood Control District	Kansas Division of Water Resources	ASCE Publication "Operation & Maintenance of Irr. & Drainage Syst."
1. Checklist	✓	✓	✓	✓	✓	✓	✓
2. Manual (explanatory)	✓	✓		✓	✓		✓
3. Rating System			✓		✓		
4. Computer Application	✓	✓					
5. Technical evaluation w/o photographs			✓	✓			✓
6. Requires professional engineer			✓	✓	✓		✓
7. Requires technical knowledge	✓	✓	✓	✓	✓		✓
8. Repearability							
9. Frequency of inspection	✓	✓	✓	✓	✓		✓

Table 6

Summary of Existing Maintenance Procedures for Bridges and Roads

Code List \ Procedures	Federal Highway Administration	PAVER	Indiana Dept. of Highways
1. Checklist	✓	✓	
2. Manual (explanatory)	✓	✓	
3. Rating System	✓	✓	
4. Computer Application	✓	✓	
5. Technical evaluation w/o photographs		✓	
6. Requires professional engineer			
7. Requires technical knowledge	✓	✓	
8. Repeatability	✓	✓	
9. Frequency of inspection	✓	✓	

Table 7

Summary of Existing Maintenance Procedures for Miscellaneous Facilities

Procedures / Code List	TRADOC	FORSCOM	California Aqueduct (Resources Agency)	U.S. Army Corps of Engineers, Southwestern Division
1. Checklist			✓	
2. Manual (explanatory)	✓	✓		
3. Rating System	✓	✓	✓	
4. Computer Application	✓			✓
5. Technical evaluation w/o photographs			✓	✓
6. Requires professional engineer				
7. Requires technical knowledge	✓	✓		
8. Repeatability	✓	✓		
9. Frequency of inspection			✓	

APPENDIX A: CHECKLISTS AND EXPLANATORY MATERIALS FOR CONCRETE/MASONRY DAMS

General Guidelines for the Observer. There are so many conditions which might endanger a dam that great care must be taken lest some be overlooked. For this reason, a checklist of questions such as the following should be used.

1. Have changes occurred in the environs of the reservoir that may necessitate reexamination of the design or of the surveillance program (e.g., industrial activities such as deep excavation, trenching, tunneling, building construction, or storage of explosives or flammable materials)?
2. Are there utilities such as oil, water, or sewerlines near or crossing the dam or its appurtenances that would jeopardize safety if they were broken?
3. Are access roads and communication lines to the damsite located and constructed so that they will not be disrupted during extreme emergency?
4. Are the structural analyses of the dam satisfactory, or should new analyses be made using the latest design technology?
5. Is the outlet capacity adequate to lower the reservoir rapidly during an emergency?
6. Is the spillway capable of discharging floodflows projected on the basis of up-to-date hydrological records?
7. Is there danger of spillway discharge undercutting the structure?
8. Are adequate auxiliary power and other redundant systems provided for hoist operation or other requirements during an emergency?
9. Is the spillway channel constructed and maintained so that there will be no dangerous erosion, or debris deposited, in the river channel?
10. Is adequate ventilation provided in shafts, tunnels, and galleries to prevent corrosion and to protect personnel from noxious gases?
11. Is essential machinery operable, especially such items as gates, valves, and hoists?
12. Are drainage sump pumps, if any, operable?
13. Are automatic alarms and telemetering devices functioning?
14. Is riprap, soil-cement, or other revetment intact as constructed?
15. Is all instrumentation in satisfactory working order.

Figure A1. Dams and public safety
(Omaha District, USBR, 1980)

16. Is there vegetation on embankments or abutments that might obscure adverse conditions from the inspector's view?
17. In the case of concrete dams, is there any reason to doubt the strength of the concrete? Has this been confirmed by nondestructive tests or tests of cores?
18. Are intake works for outlets and spillways free from silt and debris?
19. Are adequate emergency supplies and equipment available for handling adverse situations at the dam?
20. Have operating mechanisms that operate infrequently been checked or exercised to verify that they function properly?
21. Are vulnerable facilities protected against vandalism or sabotage by installation of fencing, locks, and intrusion-detection devices?
22. Are competent, trained personnel assigned to surveillance?
23. Do operations personnel have proper instructions and authority for action to be taken during an emergency?
24. Are piezometer readings and water levels in wells reasonable, steady, and consistent with reservoir height?
25. Are additional piezometers, wells, or weirs necessary for proof of safety?
26. Are reservoir linings, if any, performing as designed?
27. Are surveillance data receiving timely analyses?
28. Has the dam crest settled and thereby reduced the freeboard for flood discharge?
29. Is leakage of water excessive? Is it increasing or decreasing? Is it clear or turbi[illegible]. Are there large variations in individual drain discharges?
30. Are wet spots visible on the downstream face of the embankment or at abutment groins or immediately downstream?
31. Is there evidence of dissolution of foundation rock by seepage?
32. Is potentially dangerous seepage apparent in the vicinity from sources other than the reservoir, such as in the abutments at high level?
33. Are signs visible of any sloughing or slumping of embankments, abutments, or the reservoir environs?
34. Is piping evident, especially where fills have been placed against or covered by structures?
35. At dams with concrete face slabs, is there visible warping or other distress?
36. Has cracking developed in structures, embankments, or foundations?
37. Are there any signs of erosion of the embankment or its foundation?
38. Has any change occurred in alinement of parapet walls or retaining walls?
39. Has any recent seismic activity been recorded in the area? If so, are there any signs of detrimental effects on the reservoir or its environs?

Figure A1. (Continued)

This appendix provides guidance for performing field inspections and may serve as the basis for developing a detailed checklist for each dam.

1. Concrete Structures in General.

a. Concrete Surfaces. The condition of the concrete surfaces should be examined to evaluate the deterioration and continuing serviceability of the concrete. Descriptions of concrete conditions should conform with the appendix to "Guide for Making a Condition Survey of Concrete in Service," American Concrete Institute (ACI) Journal, Proceedings Vol. 65, No. 11, November 1968, page 905-918.

b. Structural Cracking. Concrete structures should be examined for structural cracking resulting from overstress due to applied loads, shrinkage and temperature effects or differential movements.

c. Movement - Horizontal and Vertical Alignment. Concrete structures should be examined for evidence of any abnormal settlements, heaving, deflections, or lateral movements.

d. Junctions. The conditions at the junctions of the structure with abutments or embankments should be determined.

e. Drains - Foundation, Joint, Face. All drains should be examined to determine that they are capable of performing their design function.

f. Water Passages. All water passages and other concrete surfaces subject to running water should be examined for erosion, cavitation, obstructions, leakage or significant structural cracks.

g. Seepage or Leakage. The faces, abutments and toes of the concrete structures should be examined for evidence of seepage or abnormal leakage, and records of flow of downstream springs reviewed for variation with reservoir pool level. The sources of seepage should be determined if possible.

h. Monolith Joints - Construction Joints. All monolith and construction joints should be examined to determine the condition of the joint and filler material, any movement of joints, or any indication of distress or leakage.

i. Foundation. Foundation should be examined for damage or possible undermining of the downstream toe.

Figure A2. Inspection items (HQUSACE)

j. Abutments. The abutments should be examined for sign of instability or excessive weathering.

2. Embankment Structures.

a. Settlement. The embankments and downstream toe areas should be examined for any evidence of localized or overall settlement, depressions or sink holes.

b. Slope Stability. Embankment slopes should be examined for irregularities in alignment and variances from smooth uniform slopes, unusual changes from original crest alignment and elevation, evidence of movement at or beyond the toe, and surface cracks which indicate movement.

c. Seepage. The downstream face of abutments, embankment slopes and toes, embankment - structure contacts, and the downstream valley areas should be examined for evidence of existing or past seepage. The sources of seepage should be investigated to determine cause and potential severity to dam safety under all operating conditions. The presence of animal burrows and tree growth on slopes which might cause detrimental seepage should be examined.

d. Drainage Systems. All drainage systems should be examined to determine whether the systems can freely pass discharge and that the discharge water is not carrying embankment or foundation material. Systems used to monitor drainage should be examined to assure they are operational and functioning properly.

e. Slope Protection. The slope protection should be examined for erosion-formed gullies and wave-formed notches and benches that have reduced the embankment cross-section or exposed less wave resistant materials. The adequacy of slope protection against waves, currents, and surface runoff that may occur at the site should be evaluated. The condition of vegetative cover should be evaluated where pertinent.

3. Spillway Structures. Examination should be made of the structures and features including bulkheads, flashboards, and fuse plugs of all service and auxiliary spillways which serve as principal or emergency spillways for any condition which may impose operational constraints on the functioning of the spillway.

a. Control Gates and Operating Machinery. The structural members, connections, hoists, cables and operating machinery and the adequacy of normal and emergency power supplies should be examined and tested to determine the structural integrity and verify the operational adequacy of the equipment. Where cranes are intended to be used for handling gates and bulkheads, the availability, capacity and condition of the cranes and lifting beams should be investigated. Operation of control

Figure A2. (Continued)

systems and protective and alarm devices such as limit switches, sump high water alarms and drainage pumps should be investigated.

b. Unlined Saddle Spillways. Unlined saddle spillways should be examined for evidence of erosion and any conditions which may impose constraints on the functioning of the spillway. The ability of the spillway to resist erosion due to operation and the potential hazard to the safety of the dam from such operation should be determined.

c. Approach and Outlet Channels. The approach and outlet channels should be examined for any conditions which may impose constraints on the functioning of the spillway and present a potential hazard to the safety of the dam.

d. Stilling Basin (Energy Dissipators). Stilling basins including baffles, flip buckets or other energy dissipators should be examined for any conditions which may pose constraints on the ability of the stilling basin to prevent downstream scour or erosion which may create or present a potential hazard to the safety of the dam. The existing condition of the channel downstream of the stilling basin should be determined.

4. Outlet Works. The outlet works examination should include all structures and features designed to release reservoir water below the spillway crest through or around the dam.

a. Intake Structure. The structure and all features should be examined for any conditions which may impose operational constraints on the outlet works. Entrances to intake structure should be examined for conditions such as silt or debris accumulation which may reduce the discharge capabilities of the outlet works.

b. Operating and Emergency Control Gates. The structural members, connections, guides, hoists, cables and operating machinery including the adequacy of normal and emergency power supplies should be examined and tested to determine the structural integrity and verify the operational adequacy of the operating and emergency gates, valves, bulkheads, and other equipment.

c. Conduits, Sluices, Water Passages, Etc. The interior surfaces of conduits should be examined for erosion, corrosion, cavitation, cracks, joint separation and leakage at cracks or joints.

d. Stilling Basin (Energy Dissipator). The stilling basin or other energy dissipator should be examined for conditions which may impose any constraints on the ability of the stilling basin to prevent downstream scour or erosion which may create or present a potential hazard to the safety of the dam. The existing condition of the channel downstream of the stilling basin should be determined by soundings.

Figure A2. (Continued)

e. Approach and Outlet Channels. The approach and outlet channels should be examined for any conditions which may impose constraints on the functioning of the discharge facilities of the outlet works, or present a hazard to the safety of the dam.

f. Drawdown Facilities. Facilities provided for drawdown of the reservoir to avert impending failure of the dam or to facilitiate repairs in the event of stability or foundation problems should be examined for any conditions which may impose constraints on their functioning as planned.

5. Safety and Performance Instrumentation. Instruments which have been installed to measure behavior of the structures should be examined for proper functioning. The available records and readings of installed instruments should be reviewed to detect any unusual performance of the instruments or evidence of unusual performance or distress of the structure. The adequacy of the installed instrumentation to measure the performance and safety of the dam should be determined.

a. Headwater and Tailwater Gages. The existing records of the headwater and tailwater gages should be examined to determine the relationship between other instrumentation measurements such as stream flow, uplift pressures, alignment, and drainage system discharge with the upper and lower water surface elevations.

b. Horizontal and Vertical Alignment Instrumentation (Concrete Structures). The existing records of alignment and elevation surveys and measurements from inclinometers, inverted plumb bobs, gage points across cracks and joints, or other devices should be examined to determine any change from the original position of the structures.

c. Horizontal and Vertical Movement, Consolidation, and Pore-Water Pressure Instrumentation (Embankment Structures). The existing records of measurements from settlement plates or gages, surface reference marks, slope indicators and other devices should be examined to determine the movement history of the embankment. Existing piezometer measurements should be examined to determine if the pore-water pressures in the embankment and foundation would under given conditions impair the safety of the dam.

d. Uplift Instrumentation. The existing records of uplift measurements should be examined to determine if the uplift pressures for the maximum pool would impair the safety of the dam.

e. Drainage System Instrumentation. The existing records of measurements of the drainage system flow should be examined to establish the normal relationship between pool elevations and discharge quantities and any changes that have occurred in this relationship during the history of the project.

Figure A2. (Continued)

f. Seismic Instrumentation. The existing records of seismic instrumentation should be examined to determine the seismic activity in the area and the response of the structures to past earthquakes.

6. Reservoir. The following features of the reservoir should be examined to determine to what extent the water impounded by the dam would constitute a danger to the safety of the dam or a hazard to human life or property.

a. Shore line. The land forms around the reservoir should be examined for indications of major active or inactive landslide areas and to determine susceptibility of bedrock stratigraphy to massive landslides of sufficient magnitude to significantly reduce reservoir capacity or create waves that might overtop the dam.

b. Sedimentation. The reservoir and drainage area should be examined for excessive sedimentation or recent developments in the drainage basin which could cause a sudden increase in sediment load thereby reducing the reservoir capacity with attendant increase in maximum outflow and maximum pool elevation.

c. Potential Upstream Hazard Areas. The reservoir area should be examined for features subject to potential backwater flooding resulting in loss of human life or property at reservoir levels up to the maximum water storage capacity including any surcharge storage.

d. Watershed Runoff Potential. The drainage basin should be examined for any extensive alterations to the surface of the drainage basin such as changed agriculture practices, timber clearing, railroad or highway construction or real estate developments that might extensively affect the runoff characteristics. Upstream projects that could have impact on the safety of the dam should be identified.

7. Downstream Channel. The channel immediately downstream of the dam should be examined for conditions which might impose any constraints on the operation of the dam or present any hazards to the safety of the dam. Development of the potential flooded area downstream of the dam should be assessed for compatibility with the hazard classification.

8. Operation and Maintenance Features.

a. Reservoir Regulation Plan. The actual practices in regulating the reservoir and discharges under normal and emergency conditions should be examined to determine if they comply with the designed reservoir regulation plan and to assure that they do not constitute a danger to the safety of the dam or to human life or property.

b. Maintenance. The maintenance of the operating facilities and features that pertain to the safety of the dam should be examined to determine the adequacy and quality of the maintenance procedures followed in maintaining the dam and facilities in safe operating condition.

Figure A2. (Continued)

Concrete Dam

- Upstream face _____
- Downstream face _____
- Crest
  - Roadway _____
  - Walks _____
  - Parapet wall _____
  - Lighting, etc. _____
- Galleries
  - Concrete _____
  - Metalwork _____
  - Electrical _____
  - Ventilation _____
  - Drains and drainage _____
- Elevator shaft
  - Metalwork _____
  - Equipment _____
  - Safety inspection _____
- Abutments _____
- Foundation at downstream toe of dam _____
- Leakage around dam
  - Location _____
  - Amount _____
  - Measurement methods _____
- Performance instruments and devices
  - Uplift measurements _____
  - Drain flow _____

Figure A3. Concrete dams checklist (Bureau of Reclamation RO&M Program)

UPSTREAM FACE _____

DOWNSTREAM FACE _____

General condition _____
Seepage _____

CREST

Offsets _____
Roadway _____
Walks _____
Parapet wall _____
Lighting, etc. _____

GALLERIES

Concrete _____
Metalwork _____
Electrical _____
Ventilation _____
Seepage _____
Drains and drainage (all drains should be open) _____

Frequency of cleaning or probing _____

FOUNDATION
TUNNELS

General _____
Seepage _____

INSTRUMENTATION

Structural _____
Seepage _____

ICE-PREVENTION SYSTEM _____

OTHER

_____ _____
_____ _____

ABUTMENTS

	Left	Right
FOUNDATION AT DOWNSTREAM TOE OF DAM		
Leakage around dam		
Location		
Amount		
Measurement methods		
Joint patterns		
OTHER		

Figure A4. Checklist for examination of concrete dams (Bureau of Reclamation - SEED Program)

Hole in Wall - Complete deterioration of channel wall/side slope to backfill.

Low - less then 0.25 sq. ft. in area

Med. - between 0.25 sq. ft. and 0.50 sq. ft. in area

High - greater than 0.50 sq. ft. in area

Extent of Exposed Steel - Deterioration of channel wall/side slope to reinforcement steel.

	Longitudinal steel	Transverse steel
Low	less than 5 ft. in length	Less than 2 bars/slab
Med.	5 to 20 ft. in length	2-3 bars/slab
High	more than 20 ft. in length	More than 3 bars/slab

Condition of Exposed Steel - Deterioration of exposed reinforcement steel.

Low - any reinforcement steel exposed

Med. - reinforcement steel shows excessive corrosion

High - reinforcement steel completed, corroded through

Spalling - Deterioration of channel wall/side slope to, but not including, exposure of steel.

Low - less than 1 sq. ft. in area and less than 2 inches in depth

Med. - greater than 1 sq. ft. in area and less than 2 inches in depth

High - greater than 2 inches in depth

Cracking in Wall - Horizontal and diagonal cracks.

Low - less than 0.02 inch in width and less than 24 inches in length

Med. - less than 0.02 inch in width and greater than 24 inches in length or between 0.02 inch and 0.10 inch in width

High - greater than 0.10 inch in width

Figure A5. Channel wall or wide slope distress (Los Angeles Flood Control District)

Joint Seal Damage - Ground water seepage through channel wall/side slope joints.

Low - evidence of previous seepage (small amounts of debris around joint cracks)

Med. - water and/or backfill material trickling through joints

High - water and/or backfill material running through joints

Joint Faulting - Movement of channel wall/side slope detected at construction joints.

Low - less than 0.50 inch differential between channel walls/side slopes

Med. - between 0.50 inch and 1 inch differential between channel walls/side slopes

High - more than 1 inch differential between channel walls/side slopes

Weep Holes/Rodent Activity - At channel wall/side slope weep holes, two problems can be detected: 1) plugging of weep holes so that ground water could build up behind the channel walls/side slopes; 2) tunneling through weep holes by rodents so that there may be voids in the backfill supporting the channel wall/side slope.

Low - less than 10 percent plugged or minor debris deposition on invert slab immediately below weep hole

Med - between 10 & 25 percent plugged or medium debris deposition on invert slab

High - greater than 25 percent plugged or large debris deposition on invert slab

Separation at Side Inlets

Low & Med. - no apparent separation at inlet connections to channel wall/side slope nor differential separation within side inlet

High - any apparent separation at inlet connections or differential separation within side inlet

Voids behind Channel Wall/Side Slope - Inspection made from atop channel to detect voids behind channel wall/side slope, settlement in parallel and abutting access road, or settlement of side slope.

Low - less than 2 cubic feet or void or settlement

Med. - between 2 and 5 cubic feet of void or settlement

High - greater than 5 cubic feet of void or settlement

Figure A5. (Continued)

10/04/83 CHANNEL INSPECTION SHEET O&M Area WEST
TG Page 18-B5
Facility Name: VERDUGO WASH Date 10.09.83

*Section Limits: DEECHEE WAY (STA 216+44) TO HABASSO WAY (STA 208+09) Section No. 2
Type of Channel: Rectangular X Trapezoidal
Soft Bottom Trapezoidal Channel: Yes ___ No X
Low Flow: Defined Low-Flow Channel X Undefined ___
Flow Condition at Time of Inspection: None ___ Minor in Low Flow X Major in Low Flow ___ Major ___

Inspected by: RAY P. HUGHES
Invert Walked by: RPH
Right Channel Top Walked by: ___
Left Channel Top Walked by: ___

CHANNEL INVERT DISTRESS TYPES

Cir. No.	Distress	No	Yes	Severity Low	** Med	*** High	Comments (Circle Appropriate Comments as Provided or Provide Comments)
1A	Hole in Invert		✓	✓	✓	✓	Within Confined Low-Flow: Yes No
2A	Extent of Exposed Steel		✓			✓	Adjacent to: Channel Wall (Center Line) Midway Btwn Channel Wall & Center Line
3A	Condition of Exposed Steel		✓			✓	
4A	Spalling & Pitting		✓	✓			
5A	Scour in Low-Flow		✓			✓	ENTIRE LENGTH OF LOW FLOW
6A	Cracking Longitudinal		✓		✓		Adjacent to: Channel Wall Center Line (Midway Btwn Channel Wall & Center Line)
7A	Cracking - Tranverse		✓		✓		Adjacent to: (Channel Wall) Center Line (Midway Btwn Channel Wall & Center Line)
8A	Ground Water Seepage	✓					Through: Joints Cracks
9A	Joint Faulting	✓					EVERY JOINT CAULKED WITH TAR - IN POOR CONDITION
10B	Bulging	✓					

CHANNEL WALL OR SIDE SLOPE DISTRESS TYPES

Cir. No.	Distress	No	Yes	Low	Med	High	Comments	Left Wall	Right Wall
1B	Hole in Wall/Slope	✓					Near: Toe Top		
2B	Extent of Exposed Steel		✓	✓		✓		✓	✓
3B	Condition of Exposed Steel		✓	✓		✓		✓	✓
4B	Spalling of Wall/Slope		✓	✓			SOME SPALLING HAS BEEN PATCHED	✓	✓
5B	Cracking		✓	✓			Horizontal (Diagonal)	✓	✓
6B	Joint Seal Damage	✓							
7B	Joint Faulting	✓							
8B	Weep Holes/ Rodent Act	✓					Weep Holes Plugged Rodent Activity		
9B	Separation at Side Inlets	✓							
10B	Voids behind Wall/Slope		SEE BELOW				Voids Settlement: Access Road Side Slope		

*If a section of invert or channel top is not accessible for inspection, indicate the reason for lack of access and any apparent high distresses on a sketch.
**All Med Distress types must be documented on a sketch.
***All High Distress types must be photographed and documented on a sketch.

SECTION SKETCH

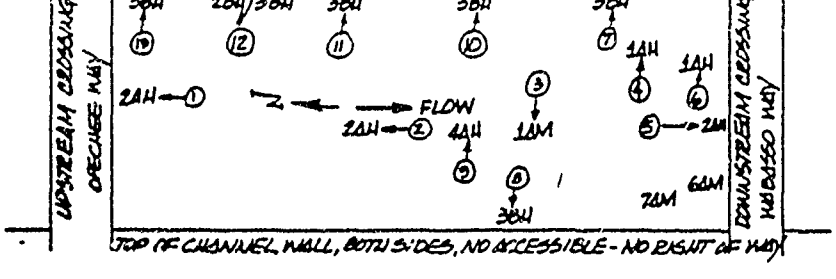


Figure A6. An example sheet of channel inspection (Los Angeles Flood Control District)

	FEATURE	CONDITION** S	CONDITION** U	Remarks (Record any change from previous inspections or condition that should be corrected)
Spillway	Upstream Face[1]			
	Downstream Face[1]			
	Deck[1,2,3]			
	Piers and Training Walls[1,3]			
	Drainage Gallery[6]			
North & South Embankments	Upstream Slope[4]			
	Downstream Slope[4]			
	Roadway[4]			
	Abutments[5]			

1. On concrete surfaces look for spalls, cracks, leaks, or movement at joints. Upstream face to be inspected from a boat semiannually at high and low reservoir.
2. On concrete decks, walls, floors, and ceilings check condition of drains, gutters, and joint filler.
3. Check paint and anchorage of handrailings, steel ladders, steel framing members, pipes, and grating.
4. On embankments check for subsidence of slopes, spalling or movement of riprap, erosion on slopes, settlement or cracks in roadway, and springs or wet areas on the downstream slope.
5. Check abutments for erosion adjacent to the dam and for springs or wet areas on the downstream side.
6. If galleries check for leaks and condition of drains and gutters, ladders, lighting, and sump as well as items noted in No. 1 above.
7. Check condition of riprap and training walls.

Figure A7. Inspection checklist for TVA

UPSTREAM FACE

	S*	U*	REMARKS
SURFACE CONDITION	x		
CRACKS / SPALLS	x		
JOINT MOVEMENT	x		
ADDITIONAL REMARKS:			

DOWNSTREAM FACE

	S	U	REMARKS
SURFACE CONDITION	x		
CRACKS / SPALLS	x		
JOINT MOVEMENT	x		
LEAKAGE	x		
ADDITIONAL REMARKS:			

ROADWAY

	S	U	REMARKS
SURFACE CONDITION	x		
CRACKS / SPALLS	x		
JOINT MOVEMENT	x		
ADDITIONAL REMARKS:			

Figure A7. (Continued)

DAM INSPECTION CHECKLIST

Date _____
Time _____

NAME OF DAM _____
FILE NUMBER _____ COUNTY _____ CLASS _____
WEATHER & SITE CONDITIONS _____
INSPECTORS _____
OTHERS _____

CONCRETE DAM TYPE _____

CHECK AREA AS INSPECTED	CHECK/CIRCLE CONDITION NOTED	OBSERVATIONS	ACTION: REPAIR	ACTION: MONITOR	ACTION: INVESTIGATE
U/S FACE	deteriorated joints				
	cracking/spalling				
CREST	deteriorated joints				
	cracking/spalling				
	poor alignment				
D/S FACE	deteriorated joints				
	cracking/spalling				
	seepage				
ABUT-MENTS	vegetation/erosion				
	sloughs/slides/cracks				
	seepage/wetness				
TOE	erosion/undermining				
	seepage/wetness				
	foundation drains				
GAL-LERY	deteriorated joints				
	cracking/spalling				
	seepage				

GENERAL COMMENTS, SKETCHES & FIELD MEASUREMENTS

Figure A8. Concrete dam inspection (Ohio Department of Natural Resources)

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SURFACES: Surface Cracks Spalling		
STRUCTURAL CRACKING		
ALIGNMENT: Vertical Horizontal		
MONOLITH JOINTS		
CONSTRUCTION JOINTS		
STAFF GAGE OR RECORDER		

Figure A9. Concrete/masonry dams (Pennsylvania Department of Environmental Resources)

FACILITY _____ DATE _____

INSPECTOR _____

Note: The items listed below are to be inspected to determine if a change has occurred or an unusual condition exists that requires maintenance, improvement, or further investigation. On items marked with an asterisk (*), notify G. O. Hydro Generation Department of any adverse condition.

Satisfactory-No Change	Requires Work or Further Investigation	Date Corrected	Job Number	
				1. Intake
				a. Log boom - submergence, condition, continuity, anchors
				b. Trash rack - clear of debris
				c. Trash rake - operation, maintenance
				d. Water surface staff gage, recorder, floatwells
				e. Excess flow device - operation, settings, pitot tube flushing
				f. Heaters
				g. Gates - condition and operability, to include electrical and mechanical equipment; is gate at proper elevation; periodic operation
				h. Cables - condition and protective coatings
				i. Lubrication (Bull. #6)
				j. Standby motor generator - maintenance, operation
				k. Security - fencing, locks, unauthorized entry
				l. Communication equipment and alarms - operability
				m. Batteries and charger - corrosion, water
				n. Housekeeping
				o. Vortexing or unusual sounds
				p. Structural stability - cracks, movement
				q. Operator and accumulator tank
				r. Other electrical and mechanical equipment
				s. Operating instructions

Figure A10. Water collection inspection checklist (PG&E)

Satisfactory-No Change	Requires Work or Further Investigation	Date Corrected	Job Number	
				2. Patrol - review frequency and method
				3. Gates - spill and cross
				4. Recorders, float wells and gages
				5. Alarms - operability and settings
				6. Grizzlies and trash rakes
				7. Rodent control on berm
				8. Vegetation control, including hazard trees adjacent to canal
				9. Leakage or wet spots - on or below berm
				10. Deer crossings and escape ramps - damage
				11. Erosion and slides - banks or berms
				12. Flow obstructions and restrictions
				13. General housekeeping, debris disposal
				14. Diversions - authorized, unauthorized (SP 028.43-1)
				15. Indications of overtopping canal or flume
				16. Spillways
				a. Flashboards or gates
				b. Chutes secure from public entry
				c. Erosion
				d. Obstructions in channels - vegetation, debris
				*e. Channel encroachments
				f. Remote controlled facilities
				g. Frequency of operation for rights (SP 483-1)

Figure A10. (Continued)

Satisfactory-No Change	Requires Work or Further Investigation	Date Corrected	Job Number		
				17.	Flumes
					a. Leakage
					b. Condition of sheets
					c. Substructure - condition
					d. Settlement
					e. Footings - erosion or ground movement, clearances around footings
					f. Walkways and handrails - employee and public safety
					g. Warning signs, public safety
				18.	Siphons
					a. Foot patrol
					b. Air valves and vents (Bull. #30)
					*c. Leakage
					*d. Supports and anchors
					e. Expansion joints
					*f. Erosion and slides
					g. Protective coatings
					h. Drains
				19.	Security-fencing and locks on valves, gates, etc.
				20.	Wire and radio communications
				*21.	Unauthorized activities in vicinity of canal - logging, roads, drilling, blasting, etc.
				22.	Copper sulfate feeders
				23.	Condition of trails

Figure A10. (Continued)

Indicator	Possible Causes	Possible Effects	Potential Remedial Measures (listed roughly in order of recommended action)
(A) Concrete (general) Cracking (shallow) Crazing Spalling	Freeze thaw cycling Reactivity Sulfate attach Leaching Aging	Accelerated deterioration Reduction of allowable stresses Reduction of effective section Increased stresses Loss of weight Increased leakage	Determine concrete qualities by testing Coring Petrographic Density Sonic (geophysical) Porosity and permeability Impact Modulus of elasticity Determine loss of section and weight Perform stress/stability analysis Protect (seal) surfaces from exposure and water Coatings Gunite Concrete Steel Remove and replace affected sections if cost-effective and if moisture can be kept out Remove (in extreme cases only)
(B) Concrete (local) Spalling and cracking	Stress concentrations Freeze thaw action Differential movement	Progressive deterioration Increase leakage Loss of section Stress concentrations	Conduct survey and establish movement monitoring system Install pins, monuments, or other devices to accurately measure opening and closing of joints Determine quality of deteriorated concrete similarly to (A) Remove and repair deteriorated sections Protect other surfaces with coatings or cover

Indicator	Possible Causes	Possible Effects	Potential Remedial Measures (listed roughly in order of recommended action)
(C) Concrete Deep cracking	Excessive loading Overstress Uplift Shrinkage (usually occurs early in life) Expansion Foundation movement Seismic activity Loss of strength Concrete creep	Increased leakage Accelerated deterioration Progressive cracking Stress redistribution Increased stresses Reduced stability Differential movement	Determine depth/extent of cracking Sonic testing Coring Interior inspection, from galleries if present Seal or grout cracks Evaluate short- and long term effects Assess effects on stresses and stress redistribution Assess potential for leakage and consequent results Determine cause Check for movement Perform loading analysis Perform stress analysis Perform stability analysis Eliminate cause if feasible Increase drainage Seal upstream face
(D) Leakage Moist or wet surfaces on concrete	Cracks Deteriorated concrete Porous concrete	Increased rate of deterioration Leaching Loss of weight Loss of strength Increased leakage	Review to determine if causes relating to (A) apply and pursue same remedial measures Determine depth and extent of cracks and see (C) for possible remedial measures
(E) Leakage Concentrated through concrete	Cracks Differential movement Open joints High uphft Leaking pipes and conduits Physical drains	Loss of concrete matrix Loss of structural integrity Increased uplift	Map location of all leaks Monitor quantities and relate to reservoir elevation and other potential influencing conditions Determine path of water if possible

Figure A11. Evaluation matrix of masonry dams (Safety of Existing Dams)

Indicator	Possible Causes	Possible Effects	Potential Remedial Measures (listed roughly in order of recommended action)
	Poor energy dissipation		Back bolt blocks or slabby rock
	Poor foundation		Increase spillway capacity to prevent overtopping
	Piping or leakage		Control spills and provide proper energy dissipation
	Poor drainage		
	Normal weathering		
(K) Inoperability of gates and valves	Failed gates	Inability to operate	Inspect operating parts and repair or replace
	Corrosion	Reduced capacity of spillways/outlets	
	Build up of mineral deposits	Increased probability of overtopping	If capacity to release water is inhibited, consider temporary change in reservoir operations
	Blockages		Methodically and systematically determine cause
	Debris		Provide corrosion protection
	Silt deposits		If ice is problem, provide barriers or aeration, see (P)
	Ice		If due to silt, debris, or other blockage, remove that cause
	Differential movements		Provide log booms, debris barriers, trash racks or other facility to alleviate blockage
(L) Reservoir slides	Unstable geology	Seiche high waves with resultant overtopping	Determine potential for waves and damage to dam
	Saturation	Silitation	Stabilize slide (see Chapter 7)
	High runoff	Blockage of outlets and spillways	Modify reservoir operation
	Sloughing	Increased loading	
		Reduction of reservoir capacity	
(M) Silitation	Geology	Increased loads	Dredge reservoir (usually economic only for small reservoirs)
	Normal or abnormal inflow	Reduced stability	Provide upstream silitation ponds
	Cultivation upstream	Plugging of outlets	Increase upstream vegetation
	Vegetation removal	Reduction of reservoir capacity	
(N) Debris	Floods	Plugging of spillways	Regularly remove debris from reservoir
	Logging	Plugging of outlets	Provide log/debris boom
	Vegetation	Damage to trash racks and equipment	Provide sluicing gate or chute to dispose of material over the dam
			Simplify spillway arrangement so debris can be passed without plugging
(O) High waves	Wind	Overtopping	Increase freeboard to prevent overtopping.
	Reservoir slides	Damage to equipment	Protect equipment against high water
		Undermining of banks	Design parapet wall to deflect waves back to reservoir.
			Provide emergency spill to skim off high water
			Treat potential slides (see Chapter 7)
(P) Ice	Cold weather	Accelerated deterioration	Operate reservoir to keep ice at level where damage will be minimal
		Blockage of spillways and outlets	Keep spillway gates open
		Damage to piping and equipment	Simplify spillway so ice can pass without restriction
		Misoperation of gates	Provide aeration near operating equipment
		Damage to trash racks	Review loadings on dam resulting from ice and assure dam can tolerate
		Parapet damage	
		Increased loading	

Figure A11. (Continued)

Indicator	Possible Causes	Possible Effects	Potential Remedial Measures (listed roughly in order of recommended action)
	Erosion or cavitation of concrete Leaching		Detail inspection Dye tests Check condition of pipes, conduits, drains, etc and repair if necessary. Assess short- and long term consequences. After determining source, try to plug or seal the crack or opening at upstream side. Determine basic cause, e.g., movement, stress conditions, and correct
(F) Leakage Through concrete (noticeable change)	Self sealing of cracks Plugged drains Broken drains Differential movement Concrete failure	Increased uplift Loss of concrete Stress redistribution	Pursue essentially same measures as for (E) Improve drainage
(G) Leakage Foundations and abutments	Foundation deterioration Inadequate drains Opening of joints, seams, shears, etc Movement	Foundation weakening with potential failure Piping through foundation Increased uplift Loss of stability Differential movement of dam Loss of revenue/water Loss of storage	Map location of all peaks Observe vegetation or other signs of moisture Infrared film a possibility Pursue measures similar to (E) Specifically assess hazards associated with slides, piping, or sloughing Seal source of leakage with impervious membrane Seal with sand cement, chemical grout, or other cutoff Provide controlled drainage system Add free draining stability material on downstream side
(H) Movement	Foundation settlement or heave Abutment movement Seismic activity Overtopping Excessive loading or uplift Concrete expansion due to chemical action	Increased leakage Inoperable appurtenances Severe cracking Stress redistribution Reduction in stability Anomalous changes in section or plan	Establish survey control system. Monuments for horizontal control – some must be sufficiently far from dam to be out of influence zone Monuments for vertical control. Pins, monuments, plates, gages, etc., across joints Inspect after each seismic event. Establish photographic record Check for changes in leakage Isolate whether cause is in foundation/abutment or dam. Review loadings Analyze foundation or abutment similarly to embankment dam Remedial measures are highly dependent on results of above
(I) Deterioration of concrete	Erosion or cavitation of concrete Leaching Movement Seismic activity Unforeseen loads	Increased cracking and spalling Increased leaks Binding of gates and operators	Same measures as for (H)
(J) Erosion and local foundation at toe of at outlets and spillway	Inadequate channel capacity Channelization of water (spills or stream flow) Lack of protection Overtopping	Undermining Local failure Complete failure of appurtenances	Channel uncontrolled flow Improve drainage with pipes, lined ditches, etc Protect eroded area with concrete, grouted rock or gabions as appropriate

Figure A11. (Continued)

APPENDIX B: CHECKLISTS AND EXPLANATORY MATERIALS FOR ROCK AND EARTH DAMS

PREVENTIVE MAINTENANCE SYSTEM

WATTS BAR LOCK — PERIOD ENDING 12/31/83 — PAGE

CTRL NO.	NOMENCLATURE	LOCATION	MODEL NUMBER	SERIAL NUMBER	FILE NUMBER	MANUFACTURE	SVC DTE
DT WRK BEG	DT WRK END	PROJ LAB	NONPROJ LAB	MTRL COST	WORK DESCRIPTION		
WBL 0004	FLOORS CONC & TRAZ	OPER BLDG & CS					/ /
04/15/80	04/15/80	40:00	200:00		REPLACED CONTROL SHELTERS		
01/25/81	01/26/81		11:30	$1,200	POURED AND FINISHED HOLE IN TERRAZZO FLOOR LEFT BY REMOVAL OF OLD SWITCHBOARD		
WBL 1020	WALLS	OPER BLDG & CS					/ /
10/19/10	10/02/40	10:00	1100:00		SANDBLASTED CAULKED AND PAINTED EXTERIOR WALLS OF OPERATIONS BLDG		
WBL 1004	MONOLITH JOINTS	LOCK WALLS					/ /
04/07/80	04/27/80		672:00		GROUTED MONOLITH JOINTS AT STATION 0+39 STA 3+20338 STA 3+54178 RIVER WALL AND STATION 3+22338 LANDWALL		
04/29/81	04/30/81	16:01	64:00		APPLIED PATCH BELOW WATER LINE AT LOWER RIVER WALL VALVE BULKHEAD SLOT		
07/19/82	07/22/82	32:00		$534	POURED JOINTS WITH 15 UNITS OF NR 200 SEALANT AND 3 UNITS OF P200 PR		
WBL 1024	VALVE BULKHEAD RECE.	LOCK WALLS					/ /
04/15/80	04/26/40		40:00		REPAIRED CAVITATION ON EMBEDDED STEEL WITH BEZOLA MOLECULAR STEEL REPAIRED DETERIATED CONCRETE WITH NORDOAK BEARING COMPOUND		

Figure B1. Maintenance work history (Nashville District)

WATTS BAR LOCK

PAGE

CONTROL NUMBER	NOMENCLATURE	LOCATION	MODEL NUMBER	SERIAL NUMBER	FILE NUMBER
INSP. CD.	SERVICES REQUIRED		LAST INSP. DATE		
WBL 1308	GATE SILLS	LOCK CHAMBER			
	A7	CHECK FOR CRACKS, LEAKS, & DETERIORATION OF CONCRETE		03/84	
WBL 1312	TILE GAGES	LOCK WALLS EMBED			
	BA	CLEAN AT INTERVALS REQUIRED TO FACILITATE READING		03/84	
	BB	CHECK FOR CRACKS, SPALLING OR ABRASION		03/84	
WBL 1316	TUNNELS & GALLERIES	LOCK WALLS			
	BC	CHECK FOR CRACKS, LEAKS, & CLOGGED DRAINS		03/84	
	BD	CHECK FOR VENTILATION & DETERIORATION OF CONCRETE		03/84	
WBL 1028	MACHINE RECESS BEAMS	LOCK WALLS			
	BG	INSPECT FOR RUST, DETERIORATION & RIGIDITY		03/84	
	BH	INSPECT FOR BROKEN WELDS & DEFECTIVE MEMBERS		05/83	
	BI	INSPECT FOR LOOSE BOLTS ON SUPPORTING ANCHORAGES		05/83	
WBL 1032	FRAMES & SUPPORTS	LOCK WALLS			
	BG	INSPECT FOR RUST, DETERIORATION & RIGIDITY		03/84	
	BH	INSPECT FOR BROKEN WELDS & DEFECTIVE MEMBERS		05/83	
	BI	INSPECT FOR LOOSE BOLTS ON SUPPORTING ANCHORAGES		05/83	
WBL 1036	GRATINGS & COVERS	LOCK WALLS			
	BG	INSPECT FOR RUST, DETERIORATION & RIGIDITY		03/84	
	BH	INSPECT FOR BROKEN WELDS & DEFECTIVE MEMBERS		05/83	
	BI	INSPECT FOR LOOSE BOLTS ON SUPPORTING ANCHORAGES		05/83	

Figure B1. (Continued)

WATTS BAR LOCK — PAGE

CONTROL NUMBER	NOMENCLATURE	LOCATION	MODEL NUMBER	SERIAL NUMBER	FILE NUMBER
INSP. CD.		SERVICES REQUIRED		LAST INSP. DATE	DELINQUENT DATE
WBL 3014	HOISTING ASSEMBLIES	LOCK VALVES			
	CT	CHECK CONNECTING PINS, SPRINGS, & CONTROL SWITCHES		09/83	04/84
WBL 9024	BRAKES GATE & VALVE	GA & VL OPER MAC			
	EH	CHECK WEAR OF BRAKE LININGS & TENSION ON BRAKE SHOES		05/83	12/83
	EI	REMOVE COVER, CLEAN & OIL ALL PIVOT POINTS		05/83	12/83
	EJ	CHECK BRAKE DRUM FOR SCORES & WEAR		05/83	12/83
	EK	CHECK NUT & KEY SECURING BRAKE DRUM OR WHEEL		05/83	12/83
	EL	CHECK BRAKE SERVOIX & MOTOR		05/83	12/83
	EM	CHECK ELECTRICAL CIRCUITS & HEATING SYSTEM		05/83	12/83
	EN	CHECK WEATHER PROOF GASKET OF COVER PLATE		05/83	12/83
WBL 9028	LIMIT SWITCHES	GA & VL OPER MAC			
	EO	REMOVE COVER		05/83	12/83
	EP	CLEAN ALL CONTACTS OR REPLACE IF NECESSARY		05/83	12/83
	EQ	CHECK ALL ELECTRICAL WIRING		05/83	12/83
	ER	LUBRICATE THREADED ROD		05/83	12/83
	ES	CHECK GASKETS & SEALS FOR MOISTURE PROOFING		05/83	12/83
	ET	CHECK HEATERS		05/83	12/83
WBL 5004	BARGE HAULAGE UNITS	MACHINERY RECESS			
	FC	INSPECT FOR WEAR OF GEARS, BEARINGS, & BRAKES		11/83	03/84
	FD	INSPECT FOR WEAR OF SHEAVES & CLUTCH LININGS		11/83	03/84
	FE	INSPECT HAULAGE CABLE		11/83	03/84
	FG	INSPECT MOTOR SLIP RINGS & CONTROLLER CONTACTOR FINGERS		11/83	03/84
WBL 6024	LIFE VESTS	OTHER FAC & EQUIP			
	GG	TEST EACH LIFE VEST FOR BUOYANCY		08/83	03/84

Figure B1. (Continued)

CNTRL NO. / INSP. CD.	NOMENCLATURE / SERVICES REQUIRED	LOCATION	MODEL NUMBER	SERIAL NUMBER	FILE NUMBER	MANUFACTURE	SVC C
				LST INSP DTE	NXT INSP DTE	INSP FREQ	LABOR(HR/MEN)
WBL 0001	NAVIGATION LOC	TENN RIVER		/	/		/ /
ZZ	NON-SCHEDULE					0:00	
WBL 0004	FLOORS CONC & TRAZ	OPER BLDG & CS					/ /
AA	EXAMINE FOR CRACKS, SETTLEMENT, & SCALING			1/84	1/85	12	2:30
AB	EXAMINE FOR DUSTING, PITTING, & DETERIORATION			1/84	1/85	12	2:45
WBL 0012	CEILINGS	OPER BLDG & CS					/ /
AE	CHECK FOR CRACKS IN PLASTER & DETERIORATED PLASTER			1/84	1/85	12	1:35
AF	CHECK FOR WATER STAINS & BROKEN OR DAMAGED ACCOUST TILE			1/84	1/85	12	1:50
AG	CHECK CONDITION OF PAINT			1/84	1/85	12	1:35
WBL 0016	ROOFS & FLASHINGS	OPER BLDG & CS					/ /
AH	INSPECT TO DETECT LEAKS & BLISTERS			4/83	4/85	12	7:30
WBL 0020	WALLS	OPER BLDG & CS					/ /
AK	CHECK FOR CRACKS IN PLASTER & WATER STAINS			1/84	1/85	12	1:40
AN	CHECK FOR MILDEW, DISFIGURATION, & OTHER DAMAGE			1/84	1/85	12	1:40
AO	CHECK FOR LOOSE MORTAR, BRICKS, & BLOCKS			1/84	1/85	12	1:40
AQ	EXAMINE EXPANSION JOINTS, SEALER, & WEATHER STRIPPING			1/84	1/85	12	1:55
AR	EXAMINE CAULKING AROUND FRAMING, STOPS, & DOOR CLOSERS			1/84	1/85	12	1:40
AS	EXAMINE LOCKS, LATCHES, SCREENS, GLAZING, & HINGES			1/84	1/85	12	2:25
AC	CHECK FOR TORN, DIRTY OR LOOSE WALL PAPER			1/84	1/85	12	1:40
WBL 0024	FOUNDATION & FOUNDATION	OPER BLDG & CS					/

Figure B1. (Continued)

Upstream face

- Riprap _____
- Erosion - Beaching _____
- Vegetative growth _____
- Settlement _____
- Debris _____

Downstream face

- Rock _____
- Vegetative growth _____

Crest

- Roadway _____
- Guardrails _____
- Curb _____
- Parapet wall _____
- Settlement _____
- Lighting _____

Abutments _____

Seepage and drainage

- Location _____
- Toe drain _____
- Measurement _____
  - Method _____
  - Amount _____
  - Change in flow _____
  - Records _____

Performance instruments

- Surface settlement points _____
- Piezometer well _____
- Readings _____

Figure B2. Checklist for earth dam (Bureau of Reclamation)

DAM

UPSTREAM FACE

Slope protection _____
Erosion–beaching _____
Vegetative growth _____
Settlement _____
Debris _____
Burrows or burrowing animals _____
Unusual conditions _____

DOWNSTREAM FACE

Signs of movement _____
Seepage or wet areas _____
Vegetative growth _____
Channelization _____
Condition of slope protection _____
Burrows or burrowing animals _____
Unusual conditions _____

ABUTMENTS

Seepage _____
Cracks, joints, and bedding planes _____
Channelization _____
Slides _____
Vegetation _____
Signs of movement _____

CREST

Surface cracking _____
Durability _____
Settlement _____
Lateral movement (alinement) _____
Camber

SEEPAGE AND DRAINAGE SUMMATION

Location(s) _____
Estimated flow(s) _____
Color (staining) _____
Erosion of outfall _____
Toe drain and relief wells _____

MEASUREMENT

Method _____
Amount _____
Change in flow _____
Clearness of flow _____

Color _____
Fines _____
Condition of measurement devices _____
Records _____

OTHER

_____ _____
_____ _____

PERFORMANCE INSTRUMENTS

Piezometer well

Well _____
Frostfloor _____
Ventilation _____
Gages _____
Piping _____
Security _____

Surface settlement points _____
Crossarm devices (deviation, station, and offset) _____
Reservoir-level gage _____
Ice-prevention system _____
Other

_____ _____
_____ _____
_____ _____
_____ _____

Figure B3. Checklist for examination of embankment dam (Bureau of Reclamation - SEED Program)

SAN LUIS DAM
INSPECTION REPORT
DATE_____

By_____ Lake Elevation____

Legend X-No Change O-Change

Item	Condition			Detailed Inspection	Photo No.	Remarks
	Requires Improvement	Sub. Std.	Std.			
Crest						
Embankment						
Downstream						
Upstream						
Groins						
Upstream						
Right						
Left						
Downstream						
Right						
Left						
Saddle Dike						
Crest						
Embankment						
Downstream						
Upstream						
Groins						
Upstream						
Right						
Left						

Figure B4. California aqueduct project surveillance

DAM INSPECTION CHECKLIST

Date _____
Time _____

NAME OF DAM _____
FILE NUMBER _____ COUNTY _____ CLASS _____
WEATHER & SITE CONDITIONS _____
INSPECTORS _____
OTHERS _____

EMBANKMENT • DIKE • LEVEE

CHECK AREA AS INSPECTED	CHECK/CIRCLE CONDITION NOTED	OBSERVATIONS	ACTION: REPAIR	ACTION: MONITOR	ACTION: INVESTIGATE
U/S SLOPE	vegetation/nprsp				
	beaching/slides/cracks				
	undermining/erosion				
CREST	ruts/erosion				
	cracks/settlement				
	poor alignment				
D/S SLOPE	vegetation/erosion				
	rodent burrows				
	sloughs/slides/cracks				
	seepage/wetness				
GROINS	vegetation/nprsp				
	erosion				
	seepage/wetness				
ABUT-MENTS	vegetation/erosion				
	sloughs/slides/cracks				
	seepage/wetness				
TOE	cracks/slumps				
	embankment drains				
	seepage/wetness				

GENERAL COMMENTS, SKETCHES & FIELD MEASUREMENTS

Figure B5. Ohio Department of Natural Resources dam inspection checklist

DAM INSPECTION CHECKLIST

Date _____
Time _____

NAME OF DAM _____
FILE NUMBER _____ INSPECTORS _____

CHECK AREA IF INSPECTED ☐

MISCELLANEOUS AREAS

	CHECK/CIRCLE CONDITION NOTED	OBSERVATIONS	ACTION: REPAIR	ACTION: MONITOR	ACTION: INVESTIGATE
MONITORING	piezometers				
	weirs				
	monuments				
GAGES	rainfall				
	pool level				
	stream				
POOL AND SHORELINE	erosion/ground cover				
	development				
	reservoir crossings				
	sedimentation				
	water quality				
WATERSHED	slopes				
	land use				
	other impoundments				
D/S AREA	stream channel				
	channel crossings				
	flood plain				
	development				
EMERG. PLAN	notification list				
	evacuation plan				
	materials/equipment				
	access road to dam				

GENERAL COMMENTS, SKETCHES & FIELD MEASUREMENTS

Figure B5. (Continued)

Yes	No		Remarks	Maintenance Tip
☐	☐	Are there any surface cracks?	May indicate movement within the dam.	Should be evaluated by a professional engineer.
☐	☐	Is there any unusual movement or cracking at or beyond the toe?	Dam or its foundation may be unstable.	Should be evaluated by a professional engineer.
☐	☐	Is there erosion on upstream face from wave action or changes in pool level?	If severe or rapid, a serious problem.	If severe and progressive, protect upstream face with riprap or other form of wave protection.
☐	☐	Is there erosion from runoff, either gullies or bare areas?	Erosion of any sort is a problem, as it tends to get worse with time if not corrected.	Improve grass cover; reshape embankment to improve drainage pattern.
☐	☐	Is there erosion from traffic (people, animals, vehicles)?	Any erosion is serious, as it will get worse with time if not corrected.	Try to keep all types of traffic to a reasonable level. Keep vehicles off dam. Stabilize crest roads to prevent rutting. Prohibit recreational vehicle traffic on slopes. Keep livestock off dam. Fill in existing ruts or eroded areas and reseed.
☐	☐	Are there any animal burrows?	May provide passageways for water into or through the dam.	Fill burrows with earth or otherwise block entry. Try to keep woodchucks, muskrat and beaver away from the dam.
☐	☐	Are there depressed areas on the dam?	May have resulted from slope failures or settlement, or even piping.	If pronounced or progressive, should be evaluated by a professional engineer.
☐	☐	Is there any evidence of piping? (This condition is evidenced by a muddy flow through the dam and/or the formation of soil deposits beyond the dam and depressions on its slopes.)	Piping is internal erosion within an embankment, or the progressive removal of soil particles adjacent to leaks through a soil mass.	Piping is always a serious condition, which can lead to failure of the dam. A piping condition should be evaluated by a professional engineer.
☐	☐	Does the crest appear to have shifted or settled excessively? (Look for cracks in the embankment and associated structures. Compare alignment with plans if they are available.)	Crest movement may indicate a stability problem. However, some settlement of a new fill, such as an embankment dam, is normal.	Should be evaluated by a professional engineer.

Figure B6. The embankment (Virginia Bureau of Water Control Management)

Yes	No		Remarks	Maintenance Tip
☐	☐	If the upstream face is protected by riprap is it in good condition? (Riprap is a layer, facing, or protective mound of stone in random size pieces, randomly placed to prevent erosion, scour, or sloughing of an embankment or structure.)	Effectiveness is lessened if riprap has slipped out of place, has been undermined, or has become overgrown with brush.	Restore riprap as necessary; keep free of trees and bushes.
☐	☐	If there is riprap in discharge channels or in the plunge pool downstream, is it in good condition?	Has riprap stone been displaced or overgrown?	Restore riprap as necessary; keep free of trees and bushes.
☐	☐	If drainage channels at ends of embankment are protected with riprap, is it in good condition?	Drainage along abutments often causes gullying if there is no protection.	Riprap or other forms of slope protection should be restored as necessary.
☐	☐	If there is riprap in miscellaneous areas (on downstream slope, on crest, etc.) is it in good repair?		Restore as necessary.
☐	☐	If there are any drains to collect and remove seepage, are they operating properly?	Check plans for the presence of drains, or search the dam to see if any are present.	Keep drains clear of any blockages and operating properly.
☐	☐	If there are foundation drain outlets, are they clear and flowing?	Foundation drains serve to collect seepage passing through the dam and conduct it away from the embankment.	Open outlets to such drains if they have become covered or damaged.
☐	☐	Are there wet spots or areas on the downstream face, at the toe, or beyond the dam? (Such spots are often indicated by a change in color or type of vegetation, such as from grass to cattails.)	*Some seepage is normal for an earth dam. Be concerned if it appears to be excessive* (a lot of standing water; very soft and marshy areas; evidence of a seepage line high on the downstream face).	*Observe seepage areas periodically to detect changes in the amount of moisture, new flows, or muddy flows.* If the upper limit of seepage is fairly high on the downstream face, the dam may be unstable.
☐	☐	Are there seeps or springs with flowing water? Look closely for these at the ends of the dam, around any pipes passing through the embankment, on downstream face, at the toe of the dam and beyond, and at the base of trees on, near, or below the dam.	Flowing seeps or springs may indicate problems, and should be observed periodically for changes in rate of flow or muddy flow. Creation of an impoundment often causes changes in the water table nearby.	Monitor seepage closely for any changes in amount, rate, extent, or clarity. Excessive or turbid seepage, or marked increases in rate of seepage, should be evaluated by a professional engineer.
☐	☐	Is there swamp or marsh type vegetation on downstream face or beyond the dam (cattails, tall grass, etc.)?	Swamp type vegetation indicates the presence of seepage.	Cut frequently to make observation of the area easier. Such growth can hide problems.

Figure B6. (Continued)

Earth Dams

Upstream Face

- ☐ Freeboard
- ☐ Wave Action
- ☐ Slope Protection
- ☐ Animal Burrows

Crest

- ☐ Erosion
- ☐ Slumps
- ☐ Cracks
- ☐ Movement

Downstream Slopes

- ☐ Abutments
- ☐ Slope Instability (slumps)
- ☐ Settlement
- ☐ Slope Protection
- ☐ Leakage
- ☐ Seepage - Embankment, toe, and downstream valley
- ☐ Erosion

Spillway Structure

- ☐ Primary Outlet - Inlet, and Trash Rack
- ☐ EMS - Approach channel, outlet channel, control section, and erosion
- ☐ Stilling Basin - Scour and Erosion
- ☐ Reservoir Drain - Operational?

Concrete Dams

- ☐ Face & Top - Surface Condition
- ☐ Cracking
- ☐ Deterioration
- ☐ Tilting - Movement
- ☐ Joints
- ☐ Abutments
- ☐ Leakage
- ☐ Seepage
- ☐ Foundation

Outlet Works

- ☐ Spillway-Type and Condition
- ☐ Gates - Method of Operation
- ☐ Stilling Basin
- ☐ Energy Dissipator

Figure B7. North Carolina Department of Natural Resources dam inspection checklist

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS		
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE		
SLOUGHING OR EROSION: Embankment Slopes Abutment Slopes		
CREST ALIGNMENT: Vertical Horizontal		
RIPRAP FAILURES		

Figure B8. Embankment inspection (Pennsylvania Department of Environmental Resources)

ITEMS TO ADDRESS		AREAS OF DAM
PROTECTION	RODENT ACTIVITY	UPSTREAM FACE
UNIFORMITY	OBSCURING GROWTH	CREST
DISPLACEMENTS	WETNESS	DOWNSTREAM FACE
CRACKING	CHANGES IN CONDITION	
EROSION		
LOCATION	EXTENT OF AREA	SEEPAGE
CHARACTERISTICS OF AR A (i.e. SOFT, BOGGY, FIRM)	CONCENTRATED FLOWS	
QUANTITY	BOILS	
TRANSPORTED OR DEPOSITED MATERIAL	COLOR	
EFFLUENT QUANTITY AND COLOR	TOE DRAIN	
DETERIORATION	OPERABILITY	OUTLET
ACCESSIBILITY	CONDITION	
CONDUIT LEAKAGE	GATE LEAKAGE	
AROUND CONDUIT	UNDERCUTTING	
DETERIORATION	CHANNEL OBSTRUCTION	SPILLWAY
CONDITION OF CONTROL SECTION	EROSION OR BACK CUTTING IN CHANNEL	
CHANNEL PROTECTION		

Figure B9. Dam inspection report form checklist
(Colorado Division of Water Resources)

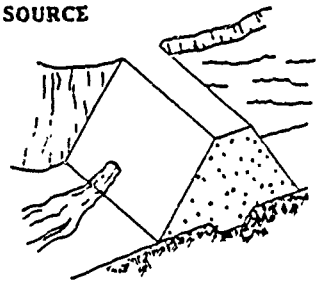
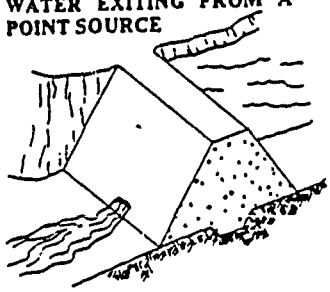
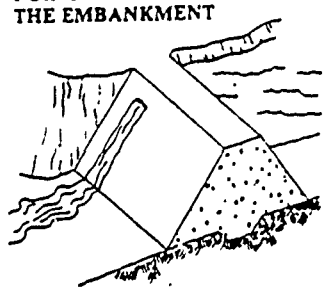
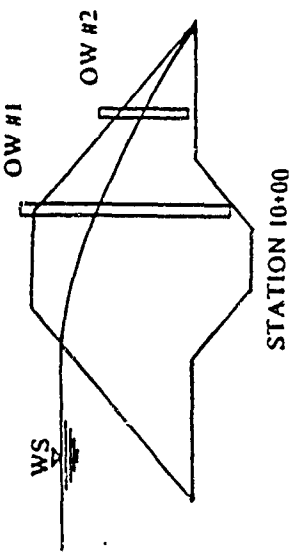
PROBLEM	CAUSES & HARM DONE	ACTION REQUIRED
5.4-1 EXCESSIVE MUDDY WATER EXITING FROM A POINT SOURCE 	**Cause:** 1. Water has created an open pathway, channel, or pipe through the dam. The water is eroding and carrying embankment material. 2. Large amounts of water have accumulated in the downstream slope. Water and embankment materials are exiting at one point. Surface agitation may be causing the muddy water. **Harm:** Continued flows can further erode embankment materials. This can lead to failure of the dam.	**Action:** 1. Begin measuring outflow quantity and establishing whether water is getting muddier, staying the same, or clearing up. 2. If quantity of flow is increasing, the water level in the reservoir should be lowered until the flow stabilizes or stops. 3. A qualified engineer should inspect the condition and recommend further actions to be taken. ENGINEER REQUIRED
5.4-2 EXCESSIVE AMOUNT OF WATER EXITING FROM A POINT SOURCE 	**Cause:** Water has created an open pathway or pipe through the dam. **Harm:** Continued flows can further erode embankment materials. This can lead to failure of the dam.	**Action:** 1. Begin measuring outflow quantity. 2. If quantity of flow is increasing, the water level in the reservoir may need to be lowered until the flow stabilizes or stops. 3. A qualified engineer should inspect the condition and recommend further actions to be taken. ENGINEER REQUIRED
5.4-3 WATER EXITING FROM A POINT SOURCE HIGH ON THE EMBANKMENT 	**Cause:** 1. Rodents, frost action, or poor construction have allowed water to create an open pathway or pipe through the embankment. **Harm:** 1. Continued flows can saturate portions of the embankment and lead to slides in the area. 2. Continued flows can further erode embankment materials and lead to failure of the dam.	**Action:** 1. Begin measuring outflow quantity. 2. If quantity of flow is increasing, the water level in the reservoir needs to be lowered until the leak stops. 3 Search for opening on upstream side and plug it if possible. 4. A qualified engineer should immediately inspect the condition and recommend further action to be taken. ENGINEER REQUIRED

Figure B9. (Continued) Dam inspection report form checklist (Colorado Division of Water Resources)

Date of Observation	Identification	Location	Elevation Top of casing	Depth to Water*	Equivalent Water Surface Elevation 3-4	Previous Elevation	Change in Elevation 5-6	Gage Rod Reading
0	1	2	3	4	5	6	7	8



Maximum Gage Rod Height _____ ft. Corresponding Reservoir Water Surface Elevation___

Comments:

_____

_____

_____

_____

_____

*If dry, write "DRY." If frozen, write "FROZEN."

Figure B9. (Continued) Observation well measurements (Colorado Division of Water Resources)

EARTH EMBANKMENTS

1. Dimensions/Shape _____

2. Foundation _____

3. Slopes _____

4. Crest _____

5. Seepage _____

6. Embankment/Abutment Junction _____

7. Drains _____

8. Staff Gage & Recorder _____

9. Other _____

Figure B10. Earth embankments (Kansas Division of Water Resources)

Vegetation on dike and within 50 feet beyond toe of dike

a. Overgrowth
   (1) Requiring cutting for dike surveillance
   (2) Requiring weed control for dike surveillance
   (3) Indicating seepage or excessive capillarity

b. Wet Terrain Vegetation
   (1) Watch for boils
   (2) Watch for sand cones, deltas, etc.
   (3) Changes with the season, pond level changes

c. Incomplete: Requiring Repair
   (1) Poor growth
   (2) Destroyed by erosion

Drainage Ditches

a. Clogged with vegetation
b. Damp
c. Flowing water: Quantity
d. Boils
e. Silt accumulations, deltas, cones

Embankment

a. Freeboard - pond level
b. Crest
   (1) Cracking
   (2) Subsidence
c. Upstream Face
   (1) Cracking
   (2) Surface erosion, gullying
   (3) Wave erosion
d. Downstream Face
   (1) Cracking
   (2) Subsidence
   (3) Bulging
   (4) Erosion, gullies
      (a) Depth
      (b) Moisture on dry days
   (5) Damp areas
   (6) Boils, seeps
e. Berm and within 50 feet beyond toe of dike
   (1) Erosion, gullies
   (2) Damp areas
   (3) Boils, seeps

Spillways

a. Intake level, boards
b. Intake structure
c. Discharge conduit condition
d. Seepage or damp areas around conduit
e. Erosion below conduit
f. Boils in vicinity of conduit
g. Spillway slabs for uplift, subsidence, crac

Areas of previous repair

a. Effectiveness of repair
b. Progression of trouble into new area

Figure B11. Checklist of conditions to be noted in safety inspections of small earth dams (Safety of Existing Dams)

Defect	Possible Indicators	Possible Causes	Effects	Potential Remedial Measures
(A) Embankment mass movement (slope failure)	Slumps on embankment face Longitudinal cracks Arcuate cracks Hummocky (irregular) slope Bulge in slope Sag in crest Bent tree trunks Misaligned guard rails or similar structures	Inadequate strength Slopes too steep Phreatic surface too high Cracking due to differential settlement Earthquake Rapid drawdown of reservoir or tailwater Large trees on dam overturned Spillway or surface drainage discharge eroding embankment Temporary saturation due to rain storms, snowmelt, or high tailwater Decaying organic material in embankment	Possible massive failure of dam Damage to spillway or outlet works, resulting in dam failure	Determine specific cause(s) by test borings, strength tests, and piezometers. Based on test results, design appropriate remedies. Some alternatives are: *Free-draining downstream buttress* Flatten slopes Lower the phreatic surface (upstream barrier, internal slurry wall or membrane cutoff, grouting) Remove and replace weak soils Control surface erosion with riprap or other means Realign-relocate appurtenant structures as required Permanent partial reduction in pool level In some cases total draining and breaching are required for safety or are more economical
(B) Embankment excessive seepage	Seepage carrying soil fines Sinkholes on embankment face Boils Concentrated seepage Unusual wetness on embankment slope Unusually soft or quick embankment slope Marsh-type vegetation on embankment slope	Lack of appropriate internal drainage Inadequate core or cutoff Inappropriate embankment material Layering of relatively permeable zones in embankment Inadequate compaction Clogging of drains or filters Burrows caused by muskrats, beavers, groundhogs, foxes, moles, chipmunks Surface erosion gullies intersecting seepage zone Temporary saturation due to rain storms, snowmelt Seepage into, out of, or along conduits and drains	Dam failure by internal erosion Structural failure due to uplift of embankment or appurtenant structures Loss of storage	Distinguishing unsafe seepage from normal seepage requires considerable judgment. Amount of change in the rate of seepage is an important factor. May require installation of piezometers to help determine seriousness. Highly concentrated seepage or evidence of internal erosion or mass movement definitely requires treatment. If it appears that seepage line is high enough to threaten mass stability, consider steps under mass movement above. *If mass movement is not indicated, a filtered drain (in the area(s) of concern is usually most appropriate.* Other alternatives: Upstream seepage barrier (blanket) Install seepage cutoff beneath crest, such as slurry wall, thin membrane wall, grouting Filtered relief wells Fill gullies with filtered drain, riprap, prevent further erosion Remove trees, replace soil Trap and remove animals In some cases total draining and breaching is the most economical safe action

Figure B12. Evaluation matrix of embankment dams

Defect	Possible Indicators	Possible Causes	Effects	Potential Remedial Measures
(C) Foundation movement	Heave of foundation near embankment toe Sinkholes Transverse or longitudinal cracks in embankment Sags in dam crest	Consolidation settlement Collapse of cavities (limestone terrane) Shear failure (usually occurs during construction and thus is usually not a problem with existing dams) Liquefaction Earthquake	Embankment failure due to loss of support, cracking, piping, mass movement Misalignment of appurtenant structures Cracking of appurtenant structures Loss of freeboard (storage) due to sags in crest	Increase embankment mass with free-draining massive downstream addition (subsurface data needed for optimal safe design) Regrade crest Realign appurtenant structures Repair appurtenant structures
(D) Foundation excessive seepage	Seepage carrying soil fines Sinkholes Boils at toe and downstream Concentrated seepage Unusually soft or quick ground	Inadequate cutoff (Re)opening of cavities (limestone terrane) Cracks due to differential settlement Fractures in foundation rock or soils	Embankment failure due to internal erosion in foundation, loss of support, collapse Loss of storage	See measures for embankment seepage (above) Downstream filtered drain trench or relief wells Upstream blanket Grouting Slurry wall or membrane Permanent reduction in reservoir pool level
(E) Unprotected slopes	Obvious visual indicators	Undersized material Disintegrating riprap Surface not properly graded Obstructed or improperly located surface drain outfalls	Deep gullying Scarched upstream slope Reduced cross section can cause structural or seepage failure	Place or augment riprap Backfill and regrade surface Place granular downstream slope protection Realign and extend discharge of spillway and surface drains as required

Figure B12. (Continued)

APPENDIX C: CHECKLISTS AND EXPLANATORY MATERIALS FOR SPILLWAYS, STILLING BASINS, AND OUTLET WORKS

PERSONNEL _____ _____ DATE _____
_____ _____ POOL _____ TAIL _____
_____ _____ PRECIP. _____

INSTRUMENTATION
SLOPE INDICATORS _____
PIEZOMETERS _____
OBSERVATION WELLS _____
SURFACE REF. PTS. _____

UPSTREAM RIGHT ABUTMENT
FLOW OF GROUNDWATER _____ NATURAL SLOPE _____
CONDITION OF RIPRAP FOR DISPLACEMENT _____ DURABILITY _____

UPSTREAM DAM SLOPE
CONDITION OF RIPRAP FOR DISPLACEMENT _____ DURABILITY _____
UNIFORMITY _____ BERM _____

UPSTREAM LEFT ABUTMENT
CONDITION OF RIPRAP FOR DISPLACEMENT _____ DURABILITY _____
DITCH _____ NATURAL SLOPE _____

DOWNSTREAM LEFT ABUTMENT
RIPRAPPED DITCH _____ NATURAL SLOPE _____

DOWNSTREAM DAM SLOPE
COVER _____ UNIFORMITY _____ RIPRAP AT TOE _____
EROSION _____ SEEPAGE _____ EXIT OF SAND DRAIN _____

DOWNSTREAM RIGHT ABUTMENT
RIPRAPPED DITCH _____ NATURAL SLOPE _____

DISCHARGE CHANNEL
CONDITION OF RIPRAP FOR DISPLACEMENT _____ DURABILITY _____

TOP OF DAM
UNIFORMITY _____ CRACKS _____ SETTLEMENT _____

SPILLWAY CUT SLOPES
UPSTREAM RIGHT SIDE _____ HORIZONTAL DRAINS _____
DOWNSTREAM LEFT SIDE _____ HORIZONTAL DRAINS _____
DOWNSTREAM RIGHT SIDE _____ HORIZONTAL DRAINS _____
DISCHARGE CHAN. RT. SIDE _____ HORIZONTAL DRAINS _____

Figure C1. Checklist for embankment and cut slopes

SPILLWAY:

GENERAL

OGEE WEIR

GRAVITY WALLS

PAVED CHUTE

CHUTE WALLS

Figure C1. (Continued)

Spillway

Approach channel

Channel _____

Log boom _____

Control structures

Crest _____

Walls _____

Apron _____

Chute

Walls _____

Floor _____

Drains _____

Stilling basin

Walls _____

Floor _____

Outlet channel

Riprap _____

Erosion _____

Vegetation _____

Structural

Hoist deck _____

Bridge _____

Gates

Mechanical features

Hoists _____

Cables _____

Gates _____

Protective coatings _____

Figure C2. Checklist on spillways (Bureau of Reclamation)

Outlet Works

Inlet structure _____

Trashracks _____

Concrete _____

Gate chamber _____

Gates

Operation at time of examination _____

Exercising frequency _____

Mechanical _____

Electrical _____

Protective coatings _____

Posted operating instructions _____

Ventilation _____

Seepage _____

Concrete _____

Access tunnel _____

Concrete _____

Metalwork _____

Outlet conduit _____

Metalwork _____

Protective coatings _____

Concrete _____

Cavitation _____

Figure C2. (Continued) Outlet works (Bureau of Reclamation RO&M Program)

Control facilities _____

Control house _____

Structural condition _____

Roof _____

Walls _____

Housekeeping _____

Metalwork _____

Protective coatings _____

Gates

Operation at time of examination _____

Exercising frequency _____

Mechanical _____

Electrical _____

Protective coatings _____

Posted operating instructions _____

Chute _____

Floor _____

Walls _____

Drains _____

Stilling basin _____

Outlet channel _____

Vegetation _____

Gravel bars, etc. _____

Figure C2. (Continued)

SPILLWAY

CONTROL STRUCTURES

Crest _____
Orifice _____

GATES AND CONTROLS

Type of gate _____
General condition _____
Protective coatings _____
Leakage (closed) _____
Exercising frequency _____
Operation of gates at time of examination _____

CONTROLS FOR GATES

Mechanical

House _____
Wire ropes _____
Protective coatings _____

Electrical

Remote control _____
Power supply _____
Standby power _____
Operation instructions _____

WEATHER DOORS

General condition _____
Protective coating _____
Exercising frequency _____
Operation at time of examination _____

CONTROLS FOR WEATHER DOORS

Mechanical

House _____
Wire ropes _____
Protective coatings _____

Electrical _____

STOPLOGS

General condition _____
Protective coating _____
Seals _____

STILLING BASIN

Walls _____
Floor _____
Weir _____
River channel below basin

Riprap _____
Erosion _____
Vegetation _____

APPROACH CHANNEL

Vegetation (trees, willows, etc.) _____
Debris _____
Slides above channel _____
Channel side slope stability _____
Log booms _____
Slope protection _____

CONTROL STRUCTURES (OBSERVED OPERATION)

Apron

Surface condition _____
General condition of concrete _____
Movement _____
Settlement _____
Joints _____
Cracks _____

Crest

Surface condition _____
General condition of concrete _____
Cracks or areas of distress _____
Signs of movement _____

Walls

Surface condition _____
General condition of concrete _____
Movement (offset) _____
Cracks or areas of distress _____
Settlement _____
Joints _____
Drains _____
Backfill _____

Gates

Condition _____
Hoist equipment _____
Control equipment _____

CHUTE OR TUNNEL

Debris
Walls _____

Surface condition _____
General condition of concrete _____
Movement (offset) _____
Settlement _____
Joints _____
Cracks or areas of distress _____
Condition of backfill _____

Floor

Surface condition _____
General condition of concrete _____

Figure C3. Spillways (Bureau of Reclamation - SEED Program)

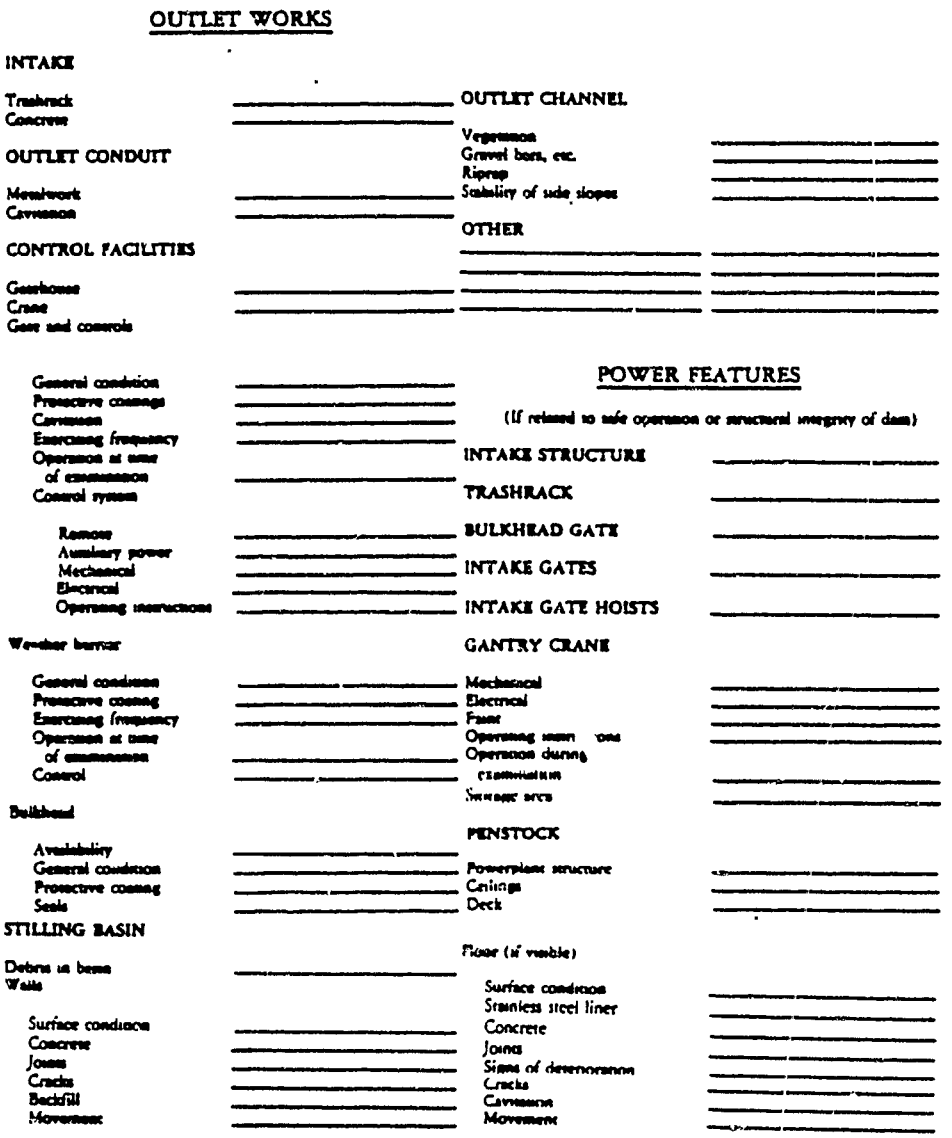


Figure C3. (Continued) Outlet works and power features (SEED Program)

PIERS

	S	U	REMARKS
SURFACE CONDITION	x		
CRACKS / SPALLS	x		
JOINT CONDITION	x		
ADDITIONAL REMARKS:			

GALLERY, EL 1002± – BLOCKS 37 THRU 43

	S	U	REMARKS
SURFACE CONDITION	x		
CRACKS / SPALLS	x		
JOINT CONDITION	x		
ADDITIONAL REMARKS:			

SLUICE GATE GALLERY, EL 880± – BLOCKS 37 THRU 44

	S	U	REMARKS
SURFACE CONDITION	x		
CRACKS / SPALLS	x		
JOINT CONDITION	x		
LEAKAGE	x		
ADDITIONAL REMARKS:			

Figure C4. Checklist on spillway
(Tennessee Valley Authority)

DAM INSPECTION CHECKLIST

Date _____
Time _____

NAME OF DAM _____
FILE NUMBER _____ INSPECTORS _____

SPILLWAYS • DRAINS • OUTLETS

CHECK AREA AS INSPECTED		CHECK/CIRCLE CONDITION NOTED	OBSERVATIONS	ACTION: REPAIR	ACTION: MONITOR	ACTION: INVESTIGATE
Principal Spillway			Type:			
INLET-L RISER		trashrack/debris				
		gates/flashboards				
		cracks/deterioration				
FLOW-L WAY		improper alignment				
		cracks/deterioration				
		joint deterioration				
STILLING L BASIN/OUTLET		type				
		cracks/deterioration				
		seepage/piping				
		undercutting				
		erosion				
		debris				
Emergency Spillway			Type:			
ALL L AREAS		vegetation/cover				
		erosion				
		obstructions				
Lake Drains/Other Outlets			Type:			
DRAINS, L OUTLETS		gates/valves				
		joints/flow surface				
		inlet tower				
		outlet area				
		operability				
TOE L DRAIN		flow amounts				
		flow clear/muddy				

GENERAL COMMENTS, SKETCHES & FIELD MEASUREMENTS

Figure C5. Checklist on spillway (ODNR)

THE PRINCIPAL SPILLWAY

Yes	No			
☐	☐	Can water flow into the principal spillway without difficulty, as intended when constructed?	*The riser, intake structure, or channel should be free of trash or other blockage.*	*Install a trash rack if one is not already in place. Periodically clear trash racks of any accumulated debris.*
☐	☐	Is outlet pipe or discharge channel clear and open to allow the free passage of the principal spillway discharge?	Flows passing through the spillway should not erode or otherwise damage the dam.	Keep outlet pipe, plunge pool, and all other outlet works clear and in good repair.
☐	☐	Is the primary spillway structure in good condition (check concrete, wood, and metal portions for damage or deterioration)?	Such dam features as the principal spillway require continued maintenance like any other structure.	Repair and maintain as appropriate to insure the continued useful life of the dam.
☐	☐	Does the lake have a drain that can be used to lower it in an emergency?	Lowering a lake may be necessary if the dam begins to develop problems.	Check plans or search dam for emergency drain system.
☐	☐	If there is an emergency drain, is it known to be in working condition? Note: If a drain has not been used for a long time, it may be possible to open it but not close it.	Drain valves and other mechanisms should receive sufficient maintenance to insure that they remain in working order.	Maintain system so that it can be used in an emergency. Normally, the pool behind an earth embankment dam should not be lowered at a rate of more than 6 inches a day.
☐	☐	If there are other gates, valves, or operating equipment, are these in working condition?	Such devices are vital to the effective and safe operation of the dam.	Repair and restore if necessary, and maintain in an operable condition.

THE EMERGENCY SPILLWAY

☐	☐	Can water flow into the emergency spillway without difficulty, as intended when constructed?	*To be effective, all portions of the spillway channel should be clear and unobstructed.*	*The approach channel should be kept free of trash, underbrush, or other blockage.*
☐	☐	Is the discharge channel clear and open to allow the free passage of the emergency spillway discharge?	Spillway flows must be effectively conducted away from the dam.	Clear as necessary.
☐	☐	Is the emergency spillway constructed in such a way that its flows will not erode other portions of the dam?	A berm is often constructed to keep spillway flows from flowing down the embankment.	Reshape dam if necessary to take care of this problem.
☐	☐	Is the emergency spillway in good condition overall (check for erosion within the channel, adequacy of grass cover, etc.)?	*Spillway erosion is a common problem.*	*Restore any erosion gullies or eroded areas.* Provide channel protection (riprap, concrete, etc.) if necessary to eliminate recurring erosion problems.

Figure C6. Principal spillway (Virginia Bureau of Water Control Management)

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SILL		
APPROACH CHANNEL		
DISCHARGE CHANNEL		
BRIDGE AND PIERS		
GATES AND OPERATION EQUIPMENT		

Figure C7. Gated spillway (Pennsylvania Department of Environmental Resources)

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT		
INTAKE STRUCTURE		
OUTLET STRUCTURE		
OUTLET CHANNEL		
EMERGENCY GATE		

Figure C7. (Continued) Outlet works (Pennsylvania Department of Environmental Resources)

Satisfactory-No Change	Requires Work or Further Investigation	Date Corrected	Job Number	
				3. Spillway
				*a) Erosion, undercutting, restrictions
				b) Debris in spillway or spill channel
				*c) Downstream encroachments in spill channel
				*d) Energy dissipator, flip bucket (visual to extent possible)
				e) Flashboards - maximum height, condition, security, when they can be installed (Bull. #54)
				f) Radial, drum, or slide gates - condition of gates, seals, chains, cables, hoist operators; periodic operation (Bull. #35)
				g) Electrical and other mechanical equipment-maintenance, operation
				h) Log boom - submergence, condition, continuity, anchors
				i) Lubrication - gate trunnions, chain links, cables, operators (Bull. #6)
				j) Siphons - clear of obstructions
				4. Fish ladder and screens-operation, gravel intrusion, condition
				5. General concrete deterioration
				6. Protective paints and coatings, particularly on submerged facilities
				7. Employee and public safety
				8. Signs, including General Recreation Warning, Maximum Water Surface, etc.
				9. Housekeeping
				10. Security - fencing, locks, unauthorized entry
				11. Fish release facilities and requirements - verify flow

Figure C8. Dams and reservoirs (PG&E)

WATER COLLECTION INSPECTION CHECKLIST

FACILITY _____ DATE _____

INSPECTOR _____

Note: The items listed below are to be inspected to determine if a change has occurred or an unusual condition exists that requires maintenance, improvement, or further investigation. On items marked with an asterisk (*), notify G. O. Hydro Generation Department of any adverse condition.

Satisfactory-No Change	Requires Work or Further Investigation	Date Corrected	Job Number	
				1. Intake
				a. Log boom - submergence, condition, continuity, anchors
				b. Trash rack - clear of debris
				c. Trash rake - operation, maintenance
				d. Water surface staff gage, recorder, floatwells
				e. Excess flow device - operation, settings, pitot tube flushing
				f. Heaters
				g. Gates - condition and operability, to include electrical and mechanical equipment; is gate at proper elevation; periodic operation
				h. Cables - condition and protective coatings
				i. Lubrication (Bull. #6)
				j. Standby motor generator - maintenance, operation
				k. Security - fencing, locks, unauthorized entry
				l. Communication equipment and alarms - operability
				m. Batteries and charger - corrosion, water
				n. Housekeeping
				o. Vortexing or unusual sounds
				p. Structural stability - cracks, movement
				q. Operator and accumulator tank
				r. Other electrical and mechanical equipment
				s. Operating instructions

Figure C8. (Continued) Tunnels (PG&E)

Satisfactory-No Change	Requires Work or Further Investigation	Date Corrected	Job Number		
				2.	Surge Chamber
					a. Road access
					b. Security - fencing, locks, unauthorized entry
					c. Spillway - erosion, undercutting, restrictions, encroachments
					d. Leakage
				3.	Adits and Portals
					a. Road access
					b. Security - fencing, locks, unauthorized entry
					c. Drain and sand/rock trap - operation, flushing
				*4.	Leakage, wet spots - at portals, adits, and along alignment
				*5.	Unauthorized activities in vicinity of tunnel - logging, roads, drilling, blasting, etc.
				6.	Ground conditions near tunnels

Notes:

Figure C8. (Continued)

Type of Defect	Causes	Effects	Remedies
Defective spillways	Insufficient analysis	Overtopping[a] Erosion or washout on downstream side	Reevaluate spillway capacity using present day hydrologic techniques
	Design error		Use watershed model simulation and prototype studies in design
	New criteria established	Erosion along and around spillway chute	Institute major repairs: Increase spillway capacity Construction of auxiliary or emergency
	Major or unprecedented events	Breach	Alternate methods:[d] Revise reservoir operating procedures Restrict reservoir utilization Require attendance of dam personnel during flood events Establish well-defined emergency procedures
Obstruction to spillways and outlet works	Excess trash[c] burden	Overtopping Erosion Damage to trash racks	Install log booms or trash racks based on use of reservoir, anticipated trash burden, etc Perform maintenance as required to remove excess trash buildup
Defective gates and hoists	Mechanical breakdown	Upsets normal operation characteristics of dam	Perform regular maintenance on mechanical equipment
	Inadequate gate seals	Vibration Excessive leakage	Check bottom gate seal for damage Provide for sharp chamfer flow foreshoft
	Cavitation around gate guides	Damage to gate frames and operating shaft	Repair cavitated areas with steel liners, check that all gate frames are securely mounted

Type of Defect	Causes	Effects	Remedies
	Differential foundation settlement	Gates becoming inoperable Gate frames crack	Repair foundation
	Trash and debris	Vibration Trash can knock gates from frames	Install trash racks
	Galvanic corrosion and/or mineral deposits	Corrode moveable parts; makes gates inoperable	Provide cathodic protection Exercise gate to prevent formation of deposits
	Poor design and/or inadequate operational procedures	Vibration	Revise operating procedures
		Unbalanced flow (can cause other problems to occur, such as buckling of steel liners and concrete erosion)	Provide adequate air vents
Defective conduits	Surface irregularities (offset joints, voids, transverse grooves, roughness)	Cavitation erosion Pipings	Grinding surface to smoothness that will prevent cavitation erosion Air vents at irregularities Require close construction tolerances Provide aeration grooves to draw air into flowing water
	Sealing in conduit	Unsteady flow conditions Structural vibrations	Perform prototype studies and modify Adequate air vents
	Unsymmetrical flow	Cavitation Erosion in stilling basins	Repair concrete Install guide vanes Baffle blocks at terminal structure Adequate air vents
	Settlement of foundations	Joint separation Structural cracking Piping	Stabilize foundations Replace joint collars Replace joint seals
	Corrosion	Piping of embankment material through holes	Replace or repair conduit

Figure C9. Evaluation matrix of appurtenant structures (Safety of Existing Dams)

Type of Defect	Causes	Effects	Remedies
Defective drainage system	Inadequate design	Uncontrolled seepage	Investigate and modify
	Improper installation	Piping	Install new or improve existing drain field
		Boils	Provide relief wells
			Reduce reservoir pool level
	Inadequate filter layer	Saturated conditions	Improve filter layer
		Seepage of lines from foundation	
	Mineral deposition	Clogging	Ream drains. Drill supplemental drains
Erosion	Inadequate design of spillways and stilling basins	Hydrostating positive to negative or uplift pressures can develop on spillways and stilling basins [can cause] cracking of concrete slabs in stilling basins and subsequent removal of embankment material; this fluctuation of pressure can demolish a spillway or stilling basin	Increase thickness of concrete slabs
			Impose tailwater elevation that will force hydraulic jump
			Provide floor drain openings in locations to avoid subjecting them to fluctuating pressures
	Structural cracks in concrete slabs of spillways and stilling basins	Water seepage through slab and eroding of embankment materials	Pressure grout cracks in slab
			Replace with thicker slab
		Development of voids under slab	Evaluate effectiveness of energy dissipators and replace if necessary
		Loss of slab support [leads to] breakup of slab	Fill voids under concrete slabs
			Anchor invert
	Unsymmetrical operation of outlet gate	Unsymmetrical loading of spillway	Operate gates symmetrically
		Scour actions in discharge area	Repair with erosion resistant aggregate and high strength concrete
		Excessive discharges	Repair with special concretes and steel plates
		Abrasive objects in stilling basin (rocks, construction debris, etc.)	Line dissipators with steel plates
		Abrasion and cavitation erosion of concrete in spillway and stilling basins	
		Damage to chute blocks and energy dissipators	Install rip rap
		Breakup of slabs and destruction of spillway	

[a] Overtopping is more critical on earth or rockfilled dams. Concrete dams can stand a limited amount of overtopping.

[b] Large trash, such as logs, etc., can damage spillways, stilling basins, and energy-dissipating blocks as it is carried over the spillway.

[c] New technique for repair; polymer impregnated concrete has been used to repair cavitation in concrete tunnels and stilling basins.

[d] New technique for repair; for spillway repair, rollcrete has been used as an alternative repair method.

Figure C9. (Continued)

APPENDIX D: CHECKLISTS AND EXPLANATORY MATERIALS FOR LOCKS, LOCKWALLS, LOCKGATES, AND OPERATING EQUIPMENT

P - M RECORD NO. _____

EQUIPMENT

COMPRESSOR, AIR 300# NO 2

COMPONENT

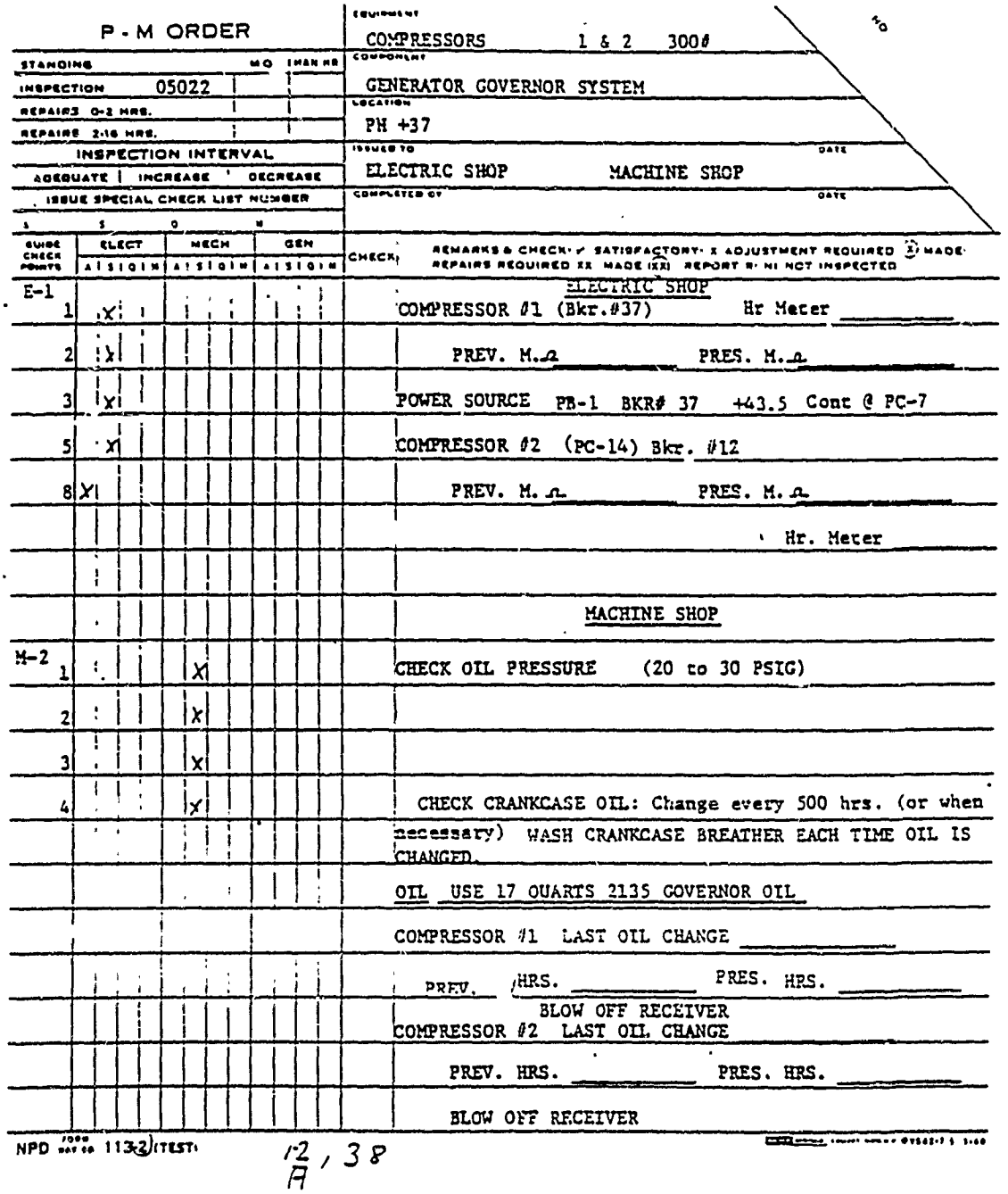
GENERATOR GOVERNOR SYSTEM

LOCATION

POWERHOUSE +37 by UNIT #6 CARD NO. ___

REPORT MADE E-M-G OR TR DATE		YES NO	REMARKS PREVENTIVE MAINTENANCE INSPECTIONS AND TROUBLE REPORTS CHARGED TO STANDING MAINTENANCE ORDERS	INSPECTIONS MAN-HOURS	BY
4-16-77	TR		COMPRESSOR WOULD NOT START. RAISED COOLIN WATER FLOW	1	AN
8-30-77	E		RMCO 42.4 HRS	1	LB
12-27-77	TR		TRIPPED ON FOUND LEADS AT MOTOR DISCONNECTED AND SHORTED TO MOTOR CASE. REPAIRED MOTOR MEGGERS TO ∞	2	R.EVANS
2-23-78	TR		COMPRESSOR TRIPPED 3 TIMES COULD FIND NOTHING WRONG	2	AN
3-1-78	TR		COMPRESSOR TRIPPED 3 TIMES COULD NOT FIND PROBLEM CHECKED TEMPS DISCHARGE WATER 110° DISCHARGE AIR 320° OIL PRESS 40 LBS RAN 2 DIFFERENT TIMES ONCE FOR 45 MIN AND ONCE FOR 30 MIN WITH NO TROUBLE	7	AN
4-17-78	PM A1		SERVICED OIL LOOKS GOOD 161. HRS.	1/2	R.EVANS
4-17-78	E PM		" ∞ MΩ	2	NEVILT
2 Nov 78	E	PM	22288 Surf.	1	RW
18 Dec 78	PM	M	" 249.9 hrs 1st. Diesel HRS. 261.4	4	NB
15 MAR 79		E	PM # 2 - BKR, KC 14 HM 2651 Oil pressure 40#	3	BW
6 Apr 79		E	PM 316.5 — Surf.	1/2	RB
25 Dec 79		M	HR (cold air breather)	3	LB
9 Oct 79		M	PM 35 psi — 321.5 hrs	1/2	JC
7 Mar 80		E	PM 383.6 hrs.	1	LB
18 Sep 80		A1	PM # 2-35.0 hrs.	2	LB
			PM 387.3 hrs.	2	LB

Figure D1. Portland/Walla Walla computer summary



P - M ORDER

STANDING | MO | MAN HR
INSPECTION 05022
REPAIRS 0-2 HRS.
REPAIRS 2-16 HRS.

INSPECTION INTERVAL
ADEQUATE | INCREASE | DECREASE

ISSUE SPECIAL CHECK LIST NUMBER
1 2 0 M

EQUIPMENT: COMPRESSORS 1 & 2 300#
COMPONENT: GENERATOR GOVERNOR SYSTEM
LOCATION: PH +37
ISSUED TO: ELECTRIC SHOP MACHINE SHOP
DATE
COMPLETED BY
DATE

GUIDE CHECK POINTS	ELECT A S Q M	MECH A S Q M	GEN A S Q M	CHECK	REMARKS & CHECK: ✓ SATISFACTORY X ADJUSTMENT REQUIRED (X) MADE REPAIRS REQUIRED XX MADE (XX) REPORT R NI NOT INSPECTED
E-1					ELECTRIC SHOP
1	X				COMPRESSOR #1 (Bkr.#37) Hr Meter
2	X				PREV. M.Ω PRES. M.Ω
3	X				POWER SOURCE PB-1 BKR# 37 +43.5 Cont @ PC-7
5	X				COMPRESSOR #2 (PC-14) Bkr. #12
8	X				PREV. M.Ω PRES. M.Ω
					Hr. Meter
					MACHINE SHOP
M-2 1		X			CHECK OIL PRESSURE (20 to 30 PSIG)
2		X			
3		X			
4		X			CHECK CRANKCASE OIL: Change every 500 hrs. (or when necessary) WASH CRANKCASE BREATHER EACH TIME OIL IS CHANGED.
					OIL USE 17 QUARTS 2135 GOVERNOR OIL
					COMPRESSOR #1 LAST OIL CHANGE
					PREV. HRS. PRES. HRS.
					BLOW OFF RECEIVER
					COMPRESSOR #2 LAST OIL CHANGE
					PREV. HRS. PRES. HRS.
					BLOW OFF RECEIVER

NPD 1133 (TEST)

12/A, 38

Figure D1. (Continued)

GENERATOR GOVERNOR SYSTEM — P-M DATA CARD

LOCATION: POWERHOUSE +37 BY UNIT — EQUIPMENT: COMPRESSOR, AIR, 300# #2.

MANUFACTURER: GARDNER DENVER CO. — COMPONENT:

DATE INSTALLED	COST PER SITE	CONTRACT OR P.O. NO.	ACCOUNT NO.
1976	12,090.	DACW57-76-C-0219	

NAME PLATE, DETAIL DESCRIPTION, REFERENCE DATA
OPERATING LIMITATIONS

INSPECTION SCHEDULES: ELECT | MECH | GEN

CONTROLS AT COMPRESSOR:

EMERGENCY STOP SWITCH:

SQUARE D CLASS 2510 TYPE FO-1 (BRINGS IN ALARM-COMPRESSOR TROUBLE)

RELAY COIL #2959-S1 SQUARE D 733A SFO
120V 60HZ 100V 50 HZ

TIMER: G.W. EALGE SIGNAL DIVISION TYPE CG 60 A6
CODE 8K 25
SH 120V 60 HZ
(BY PASSES OIL PRESSURE & LOADS COMPRESSOR)

DISCHARGE FLOW SWITCH: McDONNEL & MILLER
ITT Chicago USA
McDonnel No. FS4-3
FLOW SWITCH UL LISTED 3313 NI
MAX PRESSURE 150 lbs
MAX TEMP 300° F
RATING IN AMPS
115 VAC 7.4 F.L. 44.4A. L.R.
230 VAC 3.7A F.L. 22.2 L.R.
27

PILOT DUTY RATING A.C. 125V.A. 115-230V

DISCHARGE TEMP SWITCH: UNITED ELECTRICAL CONTROLS CO.
WATERTOWN, MASSACHUSETS, USA

TYPE	C 11	RANGE	0-325°F
MODEL	102	MFG	9-75
STOCK	No. 9037	AMPS	15
		VOLTS	125/250

Yeats Intercnge

CONTINUE ON REVERSE SIDE

NPD 113-1 (TEST)

Figure D1. (Continued)

ILLINOIS WATERWAY, ILLINOIS
DRESDEN ISLAND LOCK AND DAM

INSPECTION CHECKLIST

INSPECTION PERSONNEL:

_____ _____

_____ _____

_____ _____

DATE OF INSPECTION: _____

INSPECTION OBSERVATIONS:

1. LOCK:

General _____

_____

_____

Approach Walls

Concrete condition _____

Alignment _____

Joints _____

Other _____

Lock Walls

Concrete condition _____

Alignment _____

Joints _____

Other _____

Lower Gate Bays and Forebays

Concrete condition _____

Alignment _____

Joints _____

Other _____

Figure D2. Inspection checklist for lock and dam (Rock Island District)

Miter Gates

General condition _____

Structural details _____

Seals _____

Operating machinery _____

Tainter Valves

General condition _____

Structural details _____

Seals _____

Operating machinery _____

2. DAM:

General _____

_____

_____

Piers

Concrete condition _____

Cracks (compare with photographic records) ___

_____

_____

Tainter Gates

General condition _____

Structural details _____

Seals _____

Operating machinery _____

Roller Gates

General condition _____

Figure D2. (Continued)

Roller Gates (cont'd)

Structural details _____

Rack and Pim and Guardrail _____

Seals _____

Operating machinery _____

Service Bridge

Steel Girders _____

Bracing _____

Structural details _____

Bearings _____

Deck _____

Storage Yard

Storage yard trestle _____

Bulkheads _____

Retaining walls _____

Other _____

Earth Dike

Submersible _____

Non-submersible _____

Figure D2. (Continued)

APPENDIX E: CHECKLISTS AND EXPLANATORY MATERIALS FOR POWERHOUSES AND PUMPING PLANTS

RIN 10207A NASHVILLE DISTRICT PAGE NO 3
POWERHOUSE EQUIPMENT RUN DATE 30 MAY 84
LOCATION-J PERCY PRIEST FOR MONTH OF --JUNE

******** THE FOLLOWING EQUIPMENT IS DUE THIS MONTH FOR ROUTINE INSPECTION

EQUIPMENT NO.	NAME	TYPE TEST	FREQ MO.	TEST DATE LAST	TEST DATE NEXT	ROUTINE TIME	ROUTINE NO.	SPECIAL TIME	SPECIAL NO.	SHEET OR GUIDE NO.
40053	HEADGATE CONT.BDS + PANELS 24MO	1	24	82/06	84/06	19	6			00014000
40058	DAM SUMP PUMP MOTOR CONT. NO.1+2	1	3	84/03	84/06	72	56	109	10	00014000
40060	SUBMERSIBLE RAWWATER PMP MTR. IN DAM	1	3	84/03	84/06	59	55	12	1	00010000
40062	SUBMER. RAWWATER PMP MTR CONT INDAM	1	3	84/03	84/06	59	55			00014000
40304	MAIN CONT BDS. & PANELS	7	24	82/06	84/06	20	9	6	3	14001
41001	STA.SER.TRANSF. TEMP. IND + RELAYS	1	24	82/06	84/06	7	6			00010021
41002	STA. SER. TRANSF. INTERNAL INSP.	1	24	82/06	84/06	36	6			00011007
41250	STA. TRANSF. ACB 214	1	24	82/06	84/06	30	6			00012003
41251	STA. TRANSF. LOAD BREAK DISC 213	1	24	82/06	84/06	10	6			00016003
41253	480 VOLT MAIN AUX. BOARD + ACB'S	7	24	82/06	84/06	79	7	8	4	00013000
41352	D.C.DISTRIBUTION SYSTEM 125 VOLT	1	6	83/12	84/06	62	28			00013000
41353	D.C.DISTRIBUTION SYSTEM 48 VOLT	1	6	83/12	84/06	47	28			00013000
41354	BATTERY CHARGER NO. 1+2 125 VOLT	1	24	82/06	84/06	11	7	2	1	00018006
41653	PWRHOUSE CRANE CONT. BDS + PANELS 24	1	24	82/06	84/06	22	6			00014000
41654	POWERHOUSE CRANE TROLLEY SYSTS	1	24	82/06	84/06	39	7			000 8016
41902	STA.LIGHTING SW-GEAR PANELS + ENCLRS	1	6	83/12	84/06	64	28	272	11	00013001
41930	DRY CHEMICAL EXTINGUISHER	1	6	83/12	84/06	28	27			00013012
41986	PREFERRED AC SUPPLY + M.G. SET	1	12	83/06	84/06	21	13			00014000
42000	69 KV.TRANSF.COMB.GAS + OXYGEN TEST	1	3	84/03	84/06	76	53	14	7	00011021
42004	69 KV.TRANSF. BUSHINGS + INSULATORS	1	24	82/06	84/06	56	6			00011003
42150	69 KV.TRANSF.REACTOR INS. OIL	1	24	82/06	84/06	7	6			00011024
42151	69 KV.TRANSF.REACTOR BUSH. + INS.	1	24	82/06	84/06	9	6	48	1	00011002
42175	69 KV.TRANSF.ARRESTR.SHELL+INSULRS.	1	24	82/06	84/06	11	6			00013009
42176	69 KV.TRANSF. LGT. ARR. CONN.	1	24	82/06	84/06	8	6			00013011
42386	RESOURCE DISTRIBUTION TRANSFORMER 1	1	36	81/08	84/06	18	2			617.B
42387	RESOURCE DISTRIBUTION TRANSFORMER 2	1	36	81/08	84/06	18	2			617.B
42388	RESOURCE DISTRIBUTION TRANSFORMER 3	1	36	81/08	84/06	18	2			617.B
42500	FHSE SECURITY ELECTRICAL	1	3	84/03	84/06	16	13	116	14	
43003	RUBBER BLANKETS ELECT TEST	1	6	83/12	84/06	30	27			000 0
44002	SPILL GATE 1 CRANE + HOIST BRAKES	1	3	84/03	84/06	61	58			000 8004

E2

Figure E1. Maintenance report for powerhouse equipment (Nashville District)

PREVENTIVE MAINTENANCE NOTIFICATION INITIALS

WBL 7044 SWITCHBOARDS DUE DATE DEC 1983

S/N M/N LOCATION MISC SUPPORT SYS

DATE (MO/YR)	LBR HRS (HRS/MIN)	INSP CODE	SERVICES REQUIRED
4/84	2:45	HO	CHECK CONDITION OF WIRING, TERMINAL BLOCKS & CONNECTION
4/84	0:30	HP	CHECK CONDITION OF CONTROL SWITCHES
4/84	0:30	HQ	TEST OPERATE INFREQUENTLY USED SWITCHES
4/84	2:45	HR	INSPECT CONDITION OF INTERLOCK OR POISTIONING RELAYS
4/84	2:30	HS	INSPECT CONTACTS & MECH. CONTROLLED ELECT CONTACTORS
4/84	1:30	HT	CHECK FOR BURNING, PITTING, & CORROSION
4/84	0:30	HU	CHECK FOR PRESENCE OF DUST, RUST, & MOISTURE
4/84	1:45	HV	CHECK FOR PROPER AIR GAP, LOOSE CONNECTIONS, & WEAR
4/84	0:45	HW	CHECK FOR MISALIGNMENTS & FREEDOM OF MOVEMENT
4/84	0:30	HX	CHECK FOR LOOSE OR BROKEN SHADING RINGS
4/84	1:00	HY	CLEAN & LUBRICATE

Figure E2. Maintenance notification card (Nashville District)

	0044 RIN MAIN1 DERRICKS&CRANES	ELEC							16						2		1
1	MAINTENANCE CENTER - 2 THE DALLES DAM CENTER			PROJECT - 0 THE DALLES DAM									• DATA FOR SEP 28 DEC 82 13:31 PAGE					
0	NO. MAINTENANCE ORDER	SHOP CFY0/T	PFY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	CF		
	0044 RIN MAIN1 DERRICKS&CRANES	MECH		330	36	15			16	187	46			101	7	28	42	
		UTIL			6									16			2	
0	•	TOTAL			42	15			16	203	46			117	9	28	46	
	0046 MAIN-RIVER GATE&MACHINERY	ELEC				2		2		4			4		4		1	
	TCP=110	MECH						4	12		18	18					5	
		UTIL								4								
		RSRC								3								
0	•	TOTAL				2		6	12	11	18	18	4		4		7	
	0047 MAIN-TAINTER GATES•MACHINERY	ELEC	4	167	2	10	3	14	5	18	11	6	12	18	8	1	9	
	TCP=110	MECH		98	24	8	2	19	8	8	12	23	14	15	4	4	14	
		UTIL								10							1	
0	•	TOTAL	4		26	18	5	33	13	28	23	29	26	25	12	5	24	
	0049 MAIN-NAV LOCK UNWTRG SYSTEM	ELEC				4		8		4			5	2	4		2	
	TCP=110	MECH					2				4							
		UTIL				7												
0	•	TOTAL				11	2	8		4	4		5	2	4		4	
	0295 UNWATERING PUMP #3 REPAIR	MECH				108											10	
	080681 ESTHR= 364	UTIL				8												
0	•	TOTAL				116											11	
	0296 NAVLOCK STAFF GAGE REPL	MECH								8				35			4	
	122281 ESTHR= 184	UTIL								85	10	34		68			19	
		RSRC							17	6	4			2			2	
0	•	TOTAL							17	99	14	34		105			26	
	0297 REPLACE UPSTREAM GATE CABLES	ELEC								12							4	
	020282 ESTHR= 600 ENDMO=APR	MECH							139	758	42						93	
		RSRC								19							1	
0	•	TOTAL							139	819	42						100	
	0298 NAVLOCK GATE #1 TIMBER REPL	RSRC												19	2		2	
0	• 032382 ESTHR= 96	TOTAL												19	2		2	
	0299 POST DERRICK LIFTING BEAM PAINUTIL									51	48						9	
0	• 032982 ESTHR= 176	TOTAL								51	48						9	
	0300 NAVLOCK HANDRAIL PAINTING	MECH											41	13			5	
	013082 ESTHR= 675 ENDMO=AUG	UTIL									19	130	436	96			68	
1	MAINTENANCE CENTER - 2 THE DALLES DAM CENTER			PROJECT - 0 THE DALLES DAM									• DATA FOR SEP 28 DEC 82 13:31 PAGE					
0	NO. MAINTENANCE ORDER	SHOP CFY0/T	PFY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	CF		
0	• NAVLOCK HANDRAIL PAINTING	TOTAL									19	130	477	109			73	
	0301 N/L CONST BUILD PAINTING	UTIL											25				2	
0	• 062982 ESTHR= 48 ENDMO=JUL	TOTAL											25				2	
	0302 NAV LOCK TAINTER VALVE PUMP SLUTIL													89			8	
0	• 071282 ESTHR= 80 ENDMO=AUG	TOTAL												89			8	

Figure E3. Computer summary (Nashville)

MAINTENANCE CENTER - 2 BONNEVILLE DAM CENTER PROJECT - 2 BONNEVILLE DAM DATA FOR SEP 3 SEP 1983 PAGE 1

NO.	MAINTENANCE ORDER	SHOP CFY0/T	PFY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	CFY
		SHOP					14									14
	LEVEES & PUMPING PLANTS	TOTAL			16		209	12			38					275
<FF>	POWER FACILITIES															
5001	CUSTODIAL,INCL JANITORIAL SERVICES	ELEC	524	218	182	84								40		524
	TCP=B13	MECH	1231	155	104	84	113	107	131	133	96	111	93	83	107	1314
		TOTAL		373	286	168	113	107	131	133	96	111	93	123	107	1838
5002	RELAMP&CLN INSIDE&PORCH FIX	ELEC	30	6	3	3	6		2	3	4	2	2			30
	TCP=B10	MNTR	29	2	2			4		6	2				4	20
		TOTAL		7	5	3	6	4	2	9	6	2	2		4	50
5003	RELAMP&CLN OUTSIDE FIX	ELEC			3								16			19
	TCP=B15	TOTAL			3								16			19
5007	INSPSERV FIRE FIGHTING EQUIP	ELEC	24	11	2		6		3			2		4		28
	TCP=B10	UTIL						2		26	11		18	6		63
		OPER	69	4	16	10	7	12	4	4			4		8	69
		TRDN									2		4			6
		OSRC	4	4												4
		TOTAL		19	18	10	13	14	7	30	13	2	26	10	8	170
5011	FIL&PUR,LUB,GOV,HYDSING OILS	ELEC			29		7	73	8	14	27		2	20	4	198
	TCP=B13	MECH				9		16	8	16		14	32	12	4	116
		OSRC			2											2
		TOTAL			31	9	20	89	16	32	27	14	34	32	8	316
5021	PM CARD TASP OF STRUCTURES	ELEC			25				8	39	1	42	7	10	14	146
	TCP=110	MECH	146	7	13			16	7	33	8	62		5		151

Figure E3. (Continued)

Structural features

Building (wood, concrete, metal construction) _____

Walls _____

Roof _____

Decks _____

Drainage _____

Crane _____

Doors, windows _____

Ventilation _____

Lighting _____

Safety _____

Forebay conditions

Inlet channel _____

Concrete _____

Riprap _____

Debris or silt bars _____

Trashracks _____

Stoplogs and grooves _____

Sump conditions _____

Other metalwork _____

Pumping units

Maintenance procedures _____

Vibration _____

Cavitation _____

Lubrication _____

Bearing temperatures _____

Figure E4. Checklist for major pumping facilities (RO&M)

Pumping units - Continued

Packing box leakage _____

Paint deterioration _____

Unit mounting and foundation _____

Low water cutoff system _____

Pump priming system _____

Other operating difficulties _____

Discharge valves (manual, motor, or hydraulic-operated) _____

Operation _____

Vibration _____

Maintenance procedures _____

Lubrication _____

Paint deterioration _____

Unit mounting and foundation _____

Electrical control equipment

Housekeeping (clean and dry) _____

Protective coatings _____

Maintenance procedures _____

Other operating difficulties _____

Afterbay conditions

Discharge piping _____

Interior _____

Exterior _____

Anchor blocks _____

Discharge boxes _____

Flap valves _____

Other metalwork _____

Figure E4. (Continued)

POWER FEATURES

(If related to safe operation or structural integrity of dam)

INTAKE STRUCTURE _____

TRASHRACK _____

BULKHEAD GATE _____

INTAKE GATES _____

INTAKE GATE HOISTS _____

GANTRY CRANE

Mechanical _____
Electrical _____
Paint _____
Operating instructions _____
Operation during examination _____
Storage area _____

PENSTOCK

Powerplant structure _____
Ceilings _____
Deck _____
Walls _____
Substructure _____

TAILRACE

Draft tube closure structure _____
Draft tube bulkhead _____
Gantry crane _____

STANDBY POWER UNIT

Condition _____
Exercising frequency _____
Automatic features _____
Operation during examination _____

OTHER

_____ _____
_____ _____
_____ _____
_____ _____
_____

Figure E5. Power features (Bureau of Reclamation - SEED Program)

INSTRUMENTATION

1. Monumentation/Surveys _____

2. Observation Wells _____

3. Weirs _____

4. Piezometers _____

5. Stream Gage Recorder _____

6. Other _____

RESERVOIR

1. Slope _____

2. Bank _____

3. Sedimentation _____

4. Other _____

Figure E6. Instrumentation (Kansas Division of Water Resources)

Location_____ Circuit_____ Date of Test_____

Device_____ Mfr._____ Style Model No._____

Type of Test_____ Rating_____ Cat. Serial No._____

Transf. Ratio: Current_____ Potential_____ Sec. Z_____

Setting: Current_____Voltage_____Time Lever_____

Remarks:_____

Tested By:_____ Assisted By: _____

Miscellaneous Test Sheet

1. DATE: _____ TIME _____
2. FACILITY: _____
3. LOCATION: _____
4. DESCRIPTION OF DAMAGE: _____
5. DAMAGE CAUSED BY:
   A. TYPE OF EQUIPMENT: _____
   B. OWNER OF EQUIPMENT: _____
6. PROPOSED METHOD OF REPAIR _____
7. ARE EMERGENCY REPAIRS REQUIRED: _____
8. ESTIMATED COST OF DAMAGE OR REPAIRS: _____
9. REMARKS: _____

DATE OF REPORT: _____ SIGNED: _____

Figure E7. Report of damage to distribution system facility

APPENDIX F: CHECKLISTS AND EXPLANATORY MATERIALS FOR BRIDGES AND ROADS

	OVERALL DESCRIPTION	UNABRIDGED DESCRIPTION	SUBJECTIVE DESCRIPTION	
9	New Condition	New Condition	Good	The item is new or in good condition-no repairs necessary.
8	Good condition -no repair necessary	No repair necessary. No sign of distress or deterioration		
7	Minor items in need of repair	Includes all preventive maintenance work on any type element. A defective or deteriorated secondary-type element that probably will not progress to a serious defect if not repaired within a reasonable period of time.	Fair	The item is still performing the function for which intended. In need of minor repair.
6	Major items in need of repair	Includes progressive deterioration that can lead to possible failure, and can be arrested by maintenance repair. A defective or deteriorated major structural element vital to structural integrity of the bridge.		
5	Major repair project needed	Same as for 6 except that extent of deterioration is greater and repair may require complicated and/or extensive procedures. Major rehabilitation needed.	Poor	The item is still performing the function for which intended but at a minimum level. The item is in need of major repair.
4	Minimum adequacy to tolerate present traffic-immediate rehabilitation necessary to keep open	Major structural element is marginally adequate to support unrestricted legal load-posting should be considered. Continued observation indicates that failure is not progressive under restricted loading. This rating is relative to the class of loading using the bridge.		
3	Inadequate to tolerate present heavy load-warrants closing bridge to trucks	Major structural element deteriorated or damaged so as to reduce its capability of carrying trucks. Allow light loads only if stress check warrants and continued observation indicates failure is not progressive under light loads. Considered inadequate to tolerate legal loads and should be posted for light loads.		
2	Inadequate to tolerate any live load-warrants closing bridge to all traffic	Major structural element deteriorated or damaged so as to reduce its capability of carrying any loads. Stress check indicates structure cannot support any live load. Bridge should be closed.	Critical	The item is not performing the function for which intended.
1	Bridge repairable if desirable to reopen to traffic	Bridge closed. Bridge can be reopened with a complete rehabilitation.		
0	Bridge conditions beyond repair-danger of immediate collapse	Bridge closed. Bridge conditions are beyond repair and in danger of immediate collapse. Keep bridge closed.		

Figure F1. Condition rating (Federal Highway Bridge Replacement and Rehabilitation Program)

Federal-Aid Highway Program Manual 6-7-2-7	Overall Description		Condition Indicators (% deck area)			
Category Classification	Rating	Condition	Spalls	Delam-inations	Electrical Potential	Chloride Content #/CY
Category #3 Light Deterioration	9	New condition	none	none	0	0
	8	Good condition - no repair necessary	none	none	none > 0.35	none > 1.0
	7	Minor items need repair	none	< 2%	45% < 0.35	none > 2.0
Category #2 Moderate Deterioration	6	Major items need repair	< 2% spalls or sum of all deteriorated and/or contaminated deck concrete < 20%			
	5	Major repair project needed	< 5% spalls or sum of all deteriorated and/or contaminated deck concrete 20 to 40%			
Category #1 Extensive Deterioration	4	Minimum adequate to tolerate present traffic	> 5% spalls or sum of all deteriorated and/or contaminated deck concrete 40 to 60%			
	3	Inadequate for heavy truck loads, warrants closing bridge to truck traffic	> 5% spalls or sum of all deteriorated and/or contaminated deck concrete > 60%			
Structurally Inadequate Deck	2	Inadequate to tolerate any live load - warrants closing to all traffic	Deck structural capacity grossly inadequate			
	1	Closed bridge repairable if desired to reopen to traffic	Deck has failed completely Repairable by replacement only			
	0	Bridge beyond repair - danger of immediate collapse	Holes in deck - danger of other sections of deck failing			

Figure F1. (Continued)

TEXAS HIGHWAY DEPARTMENT

DISTRICT_____ COUNTY_____ CONTROL_____ SECTION_____ STRUCTURE NO._____ HIGHWAY_____

DESCRIPTION_____

INSPECTOR'S SIGNATURE_____ DATE_____

CONDITION RATING

9_____New Condition
8_____Good condition - no repair necessary
7_____Minor items in need of repair
6_____Major items in need of repair
5_____Major repair project needed
4_____Minimum adequacy to tolerate present traffic, immediate rehabilitation necessary to keep open
3_____Inadequacy to tolerate present heavy load - warrants closing bridge to trucks
2_____Inadequacy to tolerate any live load - warrants closing bridge to all traffic
1_____Bridge repairable, if desirable to reopen to traffic
0_____Bridge conditions beyond repair - danger of immediate collapse
N_____Not Applicable

NOTES: Enter a rating for each element of each component. Then enter an overall rating for the component. Fully supportive comments are to be made hereon or on attachments for all ratings of 7 or below.

ROADWAY

	Condition Rating
Wearing Surface	
Deck	
Joints, Expansion, Open	
Joints, Expansion, Sealed	
Joints, Other	
Drainage System	
Curbs, Sidewalks & Parapets	
Median and/or Barrier	
Railings	
Railing Protective Coating	
Delineation	
Other	
Roadway Component Rating	

Comments:

SUPERSTRUCTURE

	Condition Rating
Main Members - Steel	
Main Members - Concrete	
Main Members - Concrete, Prest.	
Main Member Connections	
Secondary Members	
Floor System Members	
Other Connections	
Expansion Bearings	
Fixed Bearings	
Steel Protective Coating	
Other	
Superstructure Component Rating	

Comments:

Figure F1. (Continued)

The sufficiency rating formula described herein is a method of evaluating factors, which are indicative of bridge sufficiency to remain in service. The result of this method is a percentage in which 100 percent would represent an entirely sufficient bridge and zero percent would represent an entirely insufficient or deficient bridge.

Ratings calculated by this formula are used by the Federal Highway Administration (FHWA) for selection of candidate bridges for the Federal Highway Bridge Replacement and Rehabilitation Program. However, prior to calculation of this rating for a given structure, the bridge is first determined to be either "Structurally Deficient" or "Functionally Obsolete". Bridges not falling into one of these two categories are not selected as candidates. Bridges with sufficiency ratings less than 50.0 are eligible for replacement or rehabilitation, and those with ratings of 80.0 or less are eligible for rehabilitation. The structurally deficient and functionally obsolete categories are defined as follows:

Structurally Deficient

1. A condition rating of 4 of less for
   Item 58 - Roadway; or
   Item 59 - Superstructures; or
   Item 60 - Substructures

or 2. An appraisal rating of 2 or less for
   Item 67 - Structural Condition; or
   Item 71 - Waterway Adequacy.[1]

Functionally Obsolete

1. An appraisal rating of 3 or less for
   Item 68 - Roadway Geometry; or
   Item 69 - Underclearances;[2] or
   Item 72 - Approach Roadway Alignment.

or 2. An appraisal rating of 3 for
   Item 67 - Structural Condition; or
   Item 71 - Waterway Adequacy.[1]

Any bridge classified as structurally deficient is excluded from the functionally obsolete category.

NOTES: [1] Item 71 applies only if the last digit of Item 42 is coded Ø, 5, 6, 7, 8 or 9.

[2] Item 69 applies only if the last digit of Item 42 is coded Ø, 1, 2, 4, 6, 7 or 8.

Figure F1. (Continued)

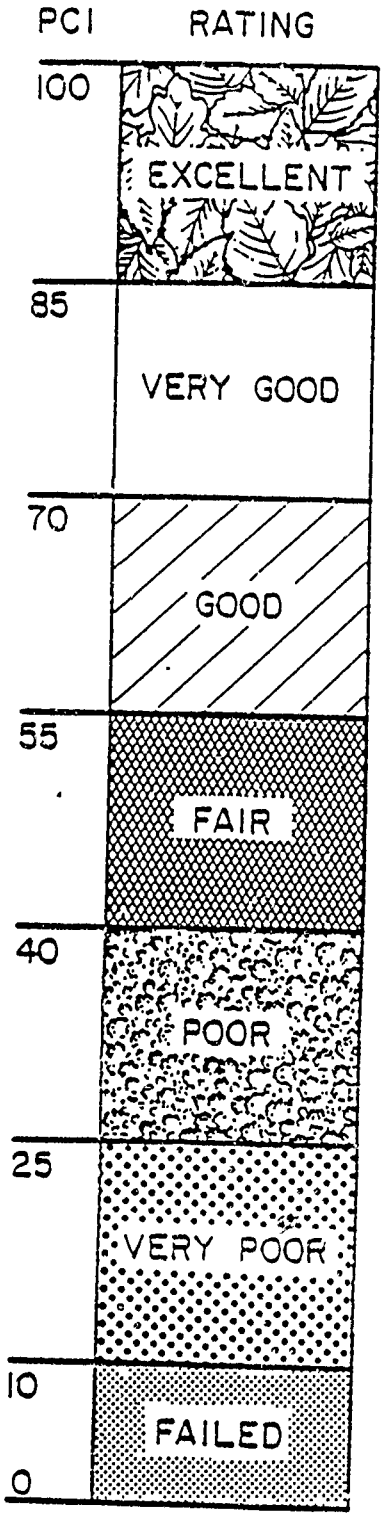


Figure F2. PCI scale and condition rating (PAVER)

REPORT DATE- 08/06/81 PCI REPORT

INSTALLATION NUMBER = 051215 FORT EUSTIS

BRANCH NUMBER	BRANCH USE	SECTION NUMBER	PCI	RATING	SURFACE TYPE	SECTION AREA/SY	PAVEMENT RANK
IMONR	ROADWAY	01	50	FAIR	AC	608	TERTIARY
	11/27/79	[FROM] NR BLDG 832			[TO]	W EDGE LUCAS PL	
IBUTN	ROADWAY	02	52	FAIR	AC	342	TERTIARY
	11/08/79	[FROM] E EDGE PATTON AVE			[TO]	W EDGE PERSHING AVE	
IMULB	ROADWAY	04	52	FAIR	AC	1683	TERTIARY
	02/20/80	[FROM] NR BLDG 3905			[TO]	END OF PAVEMENT	
I12ST	ROADWAY	03	52	FAIR	AC	399	TERTIARY
	02/11/81	[FROM] E'LY EDGE PATTON			[TO]	W'LY EDGE LEE BLVD	
IDICK	ROADWAY	01	53	FAIR	AC	966	TERTIARY
	12/03/79	[FROM] S EDGE LEE BLVD			[TO]	N EDGE TYLER AVE	
IREIN	ROADWAY	01	53	FAIR	AC	694	TERTIARY
	02/11/81	[FROM] E'LY EDGE MADISON			[TO]	W'LY EDGE WILSON LN	
IMONR	ROADWAY	05	54	FAIR	PCC	1622	SECONDARY
	12/05/79	[FROM] S EDGE TAYLOR AVE			[TO]	N EDGE BUNDY ST	
IWILN	ROADWAY	01	55	FAIR	AC	1670	TERTIARY
	11/29/79	[FROM] PERSHING AVE			[TO]	JUST BEYOND JURASIN	
IBACK	ROADWAY	01	56	GOOD	AC	5155	TERTIARY
	02/04/80	[FROM] E EDGE HARRISON RD			[TO]	W EDGE MULBRY IS RD	
ISHIF	ROADWAY	01	56	GOOD	PCC	1391	TERTIARY
	01/12/80	[FROM] BLDG 408			[TO]	BLDG 414	
ITINC	ROADWAY	01	56	GOOD	AC	3068	TERTIARY
	01/09/80	[FROM] W ED MADI BLDG 2783			[TO]	TINC02 BLDG 2798	
IMULB	ROADWAY	02	57	GOOD	AC	12551	PRIMARY
	02/20/80	[FROM] N EDGE WILSON AVE			[TO]	ENTR PINES GOLF CLB	
IKELL	ROADWAY	01	58	GOOD	AC	3378	TERTIARY
	10/30/79	[FROM] S'LY EDGE MONROE			[TO]	ROD & GUN CLUB	
I06ST	ROADWAY	01	58	GOOD	AC	2020	TERTIARY
	11/09/79	[FROM] E'LE EDGE BULLARD			[TO]	W'LY EDGE JACKSON	
IWRIG	ROADWAY	01	60	GOOD	PCC	1371	TERTIARY
	10/18/79	[FROM] E'LY EDGE WASH NO			[TO]	W'LY EDGE WALKER ST	
IKERR	ROADWAY	01	63	GOOD	AC	4897	TERTIARY
	01/16/80	[FROM] N'LY EDGE LEE BLVD			[TO]	BLDG 425 3RD PORT	
I12ST	ROADWAY	03	63	GOOD	AC	399	TERTIARY
	12/14/79	[FROM] E LY EDGE PATTON			[TO]	W'LY EDGE LEE BLVD	
I13ST	ROADWAY	02	63	GOOD	AC	1038	TERTIARY
	12/14/79	[FROM] E LY EDGE JACKSON			[TO]	W LY EDGE PATTON	
IGAFF	ROADWAY	01	64	GOOD	PCC	2152	TERTIARY
	10/22/79	[FROM] N EDGE MONROE AVE			[TO]	E EDGE LEE BLVD	
IWASN	ROADWAY	03	64	GOOD	AC	4000	PRIMARY
	11/08/79	[FROM] S'LY SIDE HINES CIR			[TO]	CENTER OF SOMERVELL	
ILEEB	ROADWAY	05	65	GOOD	AC	7688	PRIMARY
	11/15/79	[FROM] W'LY SIDE ANDERSON			[TO]	HINES CIR	
IWASN	ROADWAY	05	65	GOOD	PCC	4453	SECONDARY
	11/09/79	[FROM] S'LY EDGE TAYLOR			[TO]	N'LY EDGE WILSON	

Figure F2. (Continued)

APPENDIX G: CHECKLISTS AND EXPLANATORY MATERIALS FOR MISCELLANEOUS FACILITIES

Functional Use	Rating
Training Facilities (Cat Codes 171 and 179)	8
Technical & Industrial Facilities (Cat Codes 210 thru 452)	7
Secondary Operating Facilities (Cat Codes 720 thru 730)	6
Utilities Plants & Alarm Systems (Cat Codes 810 thru 845 and 880 thru 890)	7
Administrative Facilities (Cat Codes 610 thru 690)	4
Morale & Recreational Facilities (Cat Codes 740 thru 760)	4
Transportation & Drainage Facilities (Cat Codes 851 thru 872)	7
Real Estate (Cat Codes 900 & above)	2

(2) Justification factors for the project.

Each project listed should be essential. Therefore, it will be assigned a basic rating:

	Rating	
Essential M&R	5	Basic

Additional points will be added where project accomplishment enhances one or more of the following factors:

H	Health	.3
S	Safety	3
E	Energy Conservation	See figure G-2
I	Environmental Conditions	2
T	Security of Government Property	2
W	Morale, Welfare, or Comfort	2

Figure G1. BMAR project validation and scoring procedures (TRADOC)

H-1. TRADOC Form 641-R, BMAR/DMAR Validation (fig G-1, app G), will be used to record results of the DMAR project review. One copy of the form will be prepared by the installation for each DMAR project presented for validation or revalidation. Part I will be completed, signed by an authorized official, and placed in the project folder prior to validation visit. The TRADOC validator will complete part II of the form. Two copies of the completed form will be reproduced for TRADOC use. The completed form will become a permanent part of the project documentation folder.

H-2. Scoring of DMAR Projects.

a. A numeric score for each M&R project estimated to cost $1,000 or more will be assigned by the TRADOC validator. The assigned numeric score, in conjunction with design status, establishes a TRADOC priority system whereby projects will compete in the FHMA funding program. Factors to be considered in the score procedure are:

(1) Category of family housing.

(2) Category of requirement.

(3) Type of work.

(4) Condition of facility.

(5) Priority assigned by the installation.

b. The above factors are further subdivided to facilitate assignment of the numeric rating.

(1) Category of family housing (select only one).

Alpha Character	Category	Rating
A	Adequate housing	10
S	Substandard (including trailer sites)	8
O	Other real property	6

Figure G1. (Continued)

RUN DATE 02 NOV 81

ATEN-RAG PROJ. NO	FY	PROJECT DESCRIPTION	INSTL PRIOR	EST COST	BSG AS OF 30 SEP 80 FUNC USE SCORE	JUST FACTOR ALPHA/SCORE	PROJ TYPE ALPHA/SCORE	CONDITION ALPHA/SCORE	BASE SCORE	SEQ. NO.	IB	SCORE
3G1005511J	81	RPR LATRINES AR 32	5.0	660,000	6	5A 2.7	I 13	B 18	24	2357	5.0859	29886
3G1005611J	81	RPR (4) SWIM POOLS	6.0	60,000	6	15	I 13	C 14	16	2358	5.0238	21624
PR3007985J	78	BLDG MAINT RPRMT	10.0	133,300	45 6	1	1	1	21	2362	5.0030	21030
PR3005395J	79	RPR PAVED RDS PW	11.0	36,600	6 7	1	1	1	32	2363	6.0956	35898
PR3009285J	78	RPR/RPL FLR TILE PW	12.0	35,000	32 6	1	1	1	15	2366	6.0095	17809
PR1003515J	81	RCLR WNDW/DR HSC BLS	14.0	25,800	6	15	C 17	D 12	20	2365	6.5595	24651
PR8008685J	78	REN GUEST HSE BL 285	15.0	265,600	inc 6	1	1	1	20	2367	6.5953	25595
PR3004185J	78	RENOV BATHRMS SS	16.0	35,000	32 6	1	1	1	21	2365	6.5369	25536
PR3005385J	78	RPR EXT OF 3L A32	17.0	239,000	193 6	1	1	1	20	2367	6.4854	24685
3G1005515J	81	RPL ROOFS PW	18.0	600,000	7	15	B 19	C 14	25	2370	6.6360	29435
PR1002515J	81	RPR FLOOR BL 292	23.0	6,000	9	15 H 3.8	H 13	C 14	24	2375	6.2361	28234
3G1005115J	81	RPL LOAD DCK BMPR PW	25.0	53,000	7 S	15 3.8	L 12	C 14	21	2377	6.1792	25170
PR1003115J	81	RPR GEN FL BL 5012	27.0	79,000	6	15 3.7	I 13	D 12	16	2379	6.1129	20113
PR3005595J	79	RPL WIND/FRAME BL 67	30.0	12,000	31 6	1	1	1	24	2382	6.9369	25036
PR3005985J	78	RPR PKG AREAS PW	32.0	62,300	53 7	1	1	1	19	2384	5.9917	22991
3G1005715J	81	RPL CURB/GUTTER PW	34.0	300,000	7	15	L 12	B 18	20	2385	5.9502	23950
3G1004715J	81	RPR DRNAGE DTCH PW	35.0	186,000	7	15	L 12	C 14	18	2387	5.9307	21930
PR0000505J	80	RPR POST BRIDGES	36.0	5,000	7 S	15 3.8	1	1	1	2388	5.9119	0
PR3003705J	80	RPL SIDING AR 9	38.0	67,000	6	15	L 14	C 14	16	2390	5.8762	22576
3G1005215J	81	RPR STORM DRNAGE PW	39.0	350,000	7	15	L 12	B 18	22	2391	5.8594	25859
3G1006715J	81	RPL WND/DR AR2,18,20	41.0	44,000	8	15 4.4	L 14	D 13	19	2393	5.8273	21827
PR3007695J	79	RPL PAV RDS BL3138	42.0	24,000	7	15 3.7	C 17	B 18	29	2394	5.8120	32512
PR3005695J	79	RPL WINDOWS BL 2293	44.0	16,800	15 6	1	1	1	30	2396	5.7829	33782

Figure G2. Sample worksheet (TRADOC)

MAINTENANCE AND REPAIR (OMA, OMAR AND AFH)

Project Validation and Rating Procedures

A-1. The project validation will record results of the on-site project inspection.

A-2. The criteria governing classification of projects as maintenance and/or repair is contained in AR 420-10 and 210-50.

A-3. Rating of M&R projects including BMAR/DMAR Projects.

a. Objectives. Assignment of a numeric rating to maintenance/repair projects is accomplished to indicate the degree of need for M&R. Factors to be considered are:

(1) Facilities use Factor

(2) Project Purpose Factor

(3) Project Type Factor

(4) Mission Factor

(5) Condition Factor

(6) Installation Priority

b. The first five factors listed above are further sub-divided into functional areas to facilitate assignment of a numeric rating. Installation priority is automatically entered into scoring process in item J of Project Rating Worksheet (FORSCOM Form 63-R). (Figure A-1 and Table A-1.)

(1) Facilities Use Factor - Reflects use of facility based on Construction Category Code (select only one type). Refer to AR 415-28

Alpha Character	Type of Use	Rating Range
A	Operational Facility (Cat Codes 110 thru 169)	6-10
B	Personnel Living Space (Cat Codes 710 -714 for AFH and 720-725 for OMA & OMAR)	8-10
C	Training Facilities (Cat Codes 170 thru 179)	7-9
D	Hospital and Related Facilities (Cat Codes 510 thru 550)	7-9
E	Utilities Plants and Systems (Cat Codes 810 thru 845 and 880 thru 890)	6-9
F	Technical and Industrial Facility (Cat Codes 210 thru 452)	5-8
G	Morale and Recreational Facilities (Cat Codes 730 thru 760)	4-6
H	Transportation and Drainage Facilities (Cat Codes 850 thru 872)	4-6

Figure G3. FORSCOM priority rating system

Alpha Character	Type of Use	Rating Range
I	Administrative Facilities (Cat Codes 610 thru 690)	3-5
J	Others (Cat Codes 900 and above)	0-2

(2) Project Purpose Factor - Reflects primary purpose/area of interest of intended work. (Select Basic rating plus one or more factors as applicable.)

Alpha Character	Purpose of Maintenance and Repair	Rating Range
A	Essential Facility Maintenance/Repair	5 Basic
B	Mission (Readiness, Training)	4-5
C	Health	2-4
D	Security	1-4
E	Safety	1-4
F	Energy Conservation	4-5
G	Environmental	1-4
H	Quality of Life, Moral, Welfare, Recreational	1-4
I	Command Interest	1-3
J	Cost Effectiveness	1-3
K	Traditional, historical or architectural significance	1-3
L	Other (Specify)	1-3

(3) Project Type Factor - Reflects IFS components description codes (select one only).

IFS Code	Component Type	Rating
01	Roofing	10
02	Structure	10
03	Floor Covering	2
04	Exterior Painting	4
05	Interior Painting	3
06	Heating	10
07	Air Conditioning	6
08	Plumbing	7
09	Electrical	8
10	Equipment	8
11	Utility Plant Equipment	9

Figure G3. (Continued)

WORK FUNCTION CATEGORY WITH FEATURE COST CODE	WORK FUNC-TION CATE-GORY CODE	FUNDING LEVEL DESCRIPTIONS LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
DREDG-ING-FLOOD CONTROL (33.1)	F05	Costs of dredging to assure the design flow capacity of channels and canals during the budget year.	NONE	Costs for dredging that would provide design dimensions flood flow beyond the budget year if cost savings of greater than 45% would be achieved.	Costs for dredging that would provide design dimensions flood flow beyond the budget year if cost savings of geater than 25% would be achieved.	Costs for dredging that would provide dimensions flood flow beyond the budget year if cost savings of greater than 10% would be achieved.

Figure G4. Project operation and maintenance funding level matrix (Southwestern Division)

ITEM	P - Poor G - Good E - Excellent NC- No Change					
	P	G	E	See Note	Photo No.	Remarks
Plant Bowl						
Erosion						
Seepage						
Berms						
Pavement						
Vegetation						
Rodents						
Intake Structure						
Wingwalls						
Trash Racks						
Discharge Lines						
Pipe						
Erosion						
Outlet Structure						
Wingwalls						
Gates						
Pumping Plant						
Superstructure						
Substructure						
Motor Floor						
Pump Floor						
Valve Room						
Sleeve Coupling Chamber						
Galleries						
Water Seepage						
Pipe Leakage						
Instrumentation						
Monuments						
Piezometers						
Miscellaneous						
Water Tank						

Figure G5. Checklist for California aqueduct.